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THESIS

SPACE BASED RADAR AND ITS IMPACT ON AIRCRAFT SUSCEPTIBILITY

by

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December 1997

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13. ABSTRACT *(maximum 200 words)*

Since the US does not have the largest military force in the world, it relies on force multipliers to achieve victory. One of these force multipliers is stealth technology. However, when stealth technology is used in modern military aircraft, usually only the forward sector of the aircraft is treated and/or shaped. This forward sector treatment is effective against static, ground based radars. However, the aircraft may be very susceptible to a look-down type of radar. This thesis addresses the viability of using space-based radar to detect stealth aircraft.

Many papers have been written on how to use space-based radar to detect and track targets. However, these papers neglect to develop the satellite constellation that would be necessary to provide continuous radar coverage. These papers also do not address how susceptible stealth aircraft would be to space-based radar. The approach of this thesis was to select a target area, in this case Iraq, and develop two satellite constellations that could provide the required radar coverage. The next step was to determine if the system would be able to detect and track stealth targets.

Based on the analysis, one satellite in geosynchronous orbit can detect stealth aircraft. However, because the satellite is 35,786 km away, the power requirements, as well as the spot size are too large to track stealth aircraft. On the other hand, a constellation of 32 satellites in low earth orbit (1000 km) can both detect and track stealth aircraft. In conclusion, if the US does not start applying stealth technology to the upper surface of stealth aircraft, they will be susceptible to space-based radar.

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SPACE BASED RADAR AND ITS IMPACT ON AIRCRAFT SUSCEPTIBILITY

W. Alan Ricks
B.S., University of Maryland, 1994

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of the requirements for the degree of

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ABSTRACT

Since the US does not have the largest military force in the world, it relies on force multipliers to achieve victory. One of these force multipliers is stealth technology. However, when stealth technology is used in modern military aircraft, usually only the forward sector of the aircraft is treated and/or shaped. This forward sector treatment is effective against static, ground based radars. However, the aircraft may be very susceptible to a look-down type of radar. This thesis addresses the viability of using space-based radar to detect stealth aircraft.

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I would like to thank Analytical Graphics for allowing me to use some of the diagrams contained in their book "Satellite Tool Kit an Astronautics Primer." These diagrams were used in Chapter III to help explain basic astronautical terms.

I especially thank Analytical Graphics for allowing me to use their professional version of Satellite Tool Kit (STK 4.0). Their software program was used extensively in the development of my thesis. The two different satellite configurations in Chapter IV were developed in a few weeks using STK 4.0, rather than a few months had it been done by hand. All of the diagrams showing the constellation design and ground tracks were generated using STK 4.0.

I would also like to thank Professor Ball at the Naval Postgraduate School for helping me complete my thesis as part of the NAVAIR/NPS distance learning program. His support to the distance learning program has allowed me and many other professionals to continue their education.

I. INTRODUCTION

The purpose of this thesis is to examine the impact space-based radar will have on the combat susceptibility of current and future United States military aircraft. Combat susceptibility, in simple terms, refers to the probability an aircraft will be hit by a weapon. Several sequences lead to the aircraft getting hit by a round, missile, or directed energy weapon. The first two phases are detection and tracking by a surveillance or tracking sensor. Stealth, the ability of an aircraft to delay detection or degrade tracking, can significantly lower an aircraft's susceptibility. However, space-based radar could pose a significant threat to stealth technology.

The current design trend for stealth aircraft is to take the incoming radar energy and bounce what can not be absorbed into a direction away from the mono-static radar. This task is mainly accomplished by treating certain sections of the aircraft, namely the frontal sector of the aircraft. The upper surface of most stealth aircraft is usually ignored or receives very little treatment. For ground-based radars, this does not present a problem. However, for a space-based radar, this neglect could pose a real problem.

With spacecraft launch costs dropping and the miniaturization of computer and radar equipment (the lighter the payload, the cheaper the cost), more and more countries are gaining access to space. Table 1 shows a list of countries that currently have access to space as of October 1994 [Ref. 1: p. 7] .

Space -Capable Nations	
Level	**Country**
First Tier	United States
	Russia
Second Tier	France
	Great Britain
	China
	Japan
	India
	Israel
Third Tier*	Brazil
	Italy
* Not all inclusive, only major nations	Australia
listed.	Thailand
	South Africa
	Canada
	Iran
	Iraq
	Pakistan

Table 1.

Tier 1 represents space-capable nations that possess both military and civilian space capabilities that are on the cutting edge of technology. Second tier nations have dual purpose space systems that serve both civilian and military purposes. The third tier countries purchase or lease space capabilities from tier 1 and 2 countries. [Ref. 1]

Based on the data contained in Table 1, today, most countries do not pose a threat to US stealth aircraft. However, the acquisition process for a new system can take from 10 to 15 years and new weapons platforms are expected to last at least 30 years or more. This means that the systems we design today, must be able to handle threats in the year 2037 and beyond. At the given rate of technological growth, there will be many

more countries in the future with satellite capabilities. These satellites may carry radar systems capable of detecting and tracking stealth aircraft.

It should be pointed out that while this thesis addresses the impact of space-based radar, there are two other major counter stealth detection technologies available. The first is optical detection. It is now possible to buy space-based optical systems off the shelf that can give resolutions up to 1 meter [Ref.2]. These systems are not classified and are available to anyone. The advantage of using optics is that very little power is required to view the target (compared to radar). The reason for this is that unlike radar, the visual image only has to make a one way trip to the satellite verses a round trip required by radar. The disadvantage of using optics is that viewing times are limited by the weather (clouds) and lighting conditions.

The second form of detection technology that could be used is infrared sensing. Infrared systems also require less energy than radar and allow for nighttime viewing. Infrared systems provide better coverage in weather than optics, but they still have more limitations than radar (energy is still absorbed by clouds and rain). A realistic satellite detection system would most likely encompass a combination of visual, infrared, and radar technologies.

This thesis will examine space-based radar applications and determine if the technology is a viable threat to US stealth aircraft. Chapter II will discuss basic radar principles, Chapter III will provide a brief overview of orbital mechanics, and Chapter

IV will address the viability of using space-based radar to detect stealth aircraft. The final chapter will discuss the conclusions.

II. BASIC RADAR PRINCIPLES

The purpose of this chapter is to provide a brief overview of radar fundamentals. Radar is a very complicated subject and can not be adequately addressed in a few pages. However, the basic principles and concepts will be presented in order to provide the reader with the tools necessary to understand the premise of this thesis.

Radar (Radio Detection and Ranging) is the process of using electromagnetic waves to detect and track a target. Radio waves have a wide range of frequencies. The frequency, f , is the number of times a radar wave passes a given point in space (in a given amount of time) and is inversely related to the wavelength (wavelength, $\lambda = c/f$, where c is the speed of light) . The higher the frequency, the smaller the wavelength. Radar systems work by transmitting an electromagnetic wave from the radar antenna, to the target at the speed of light ($3X10^8$ m/s). The energy that hits the target is scattered in different directions. The energy that bounces back in the direction of the radar appears as a blip on the radar screen. The goal is to get the largest amount of energy returned to the radar.

An antenna is used to transmit and receive radio waves. An omni-directional antenna radiates energy equally in all directions. The target is going to be located in a certain sector. By taking the energy being radiated into unoccupied sectors (wasted energy) and focusing it in the direction of the target, larger signal returns will be received and allow the target to be detected at greater distances. The red circle in Figure 1. shows

the radar energy being radiated equally in all directions. The black colored lobe shows the energy being directed to a specific sector (referred to as gain, G) [Ref. 3]. The larger the gain, the larger the directivity. If the radar energy is focused in a particular direction, scans need to be performed to locate the target (radar dishes rotate in order to locate the target). Scans can be performed rapidly, therefore, in most cases, the benefit from using gain is not significantly hindered by limited exposure time.

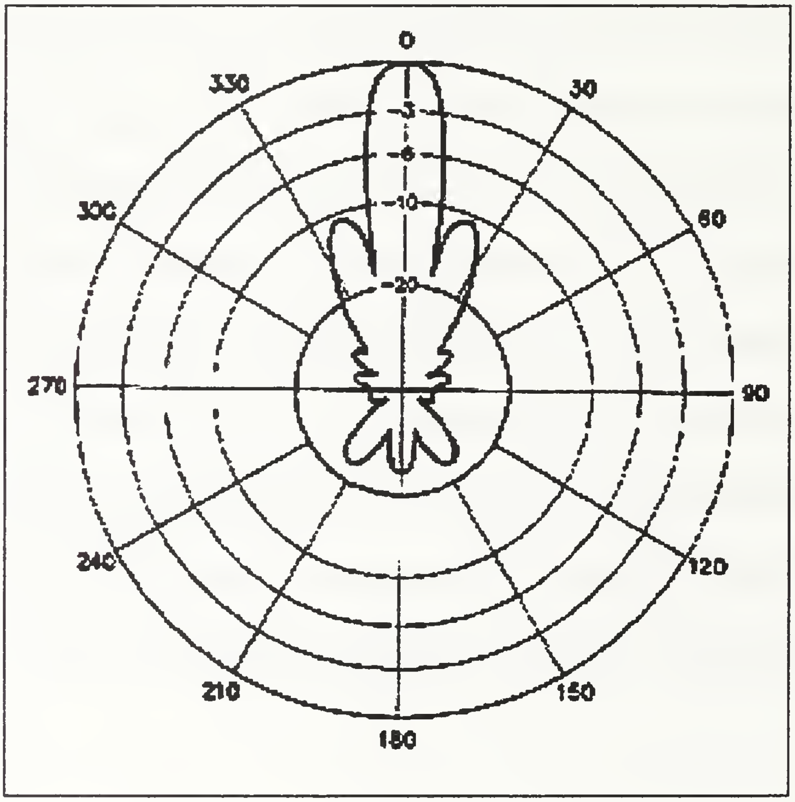


Figure 1.

The equation for the received signal energy (without losses) is given below (one form of the Radar Range Equation). The reader is directed to Appendix B of Professor Ball's book, The Fundamentals of Aircraft Combat Survivability Analysis and Design, for a derivation [Ref. 4].

$$S = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4}$$

Where P_t is the power transmitted, R is the range, and σ is the radar cross section. The radar cross section is a measure of how much energy is scattered in the direction of the radar. Measurements are typically taken all the way around the aircraft (360° in azimuth) with the nose located at 0°. Measurements are also taken with the aircraft pitched at varying degrees (usually around +/- 5°). The data is measured in square meters or decibels, with one square meter being the reference level (dB_{sm}). Figure 2. shows a typical signature pattern for an aircraft [Ref. 5]. An aircraft with a large signature will be detected before an aircraft with a small signature.

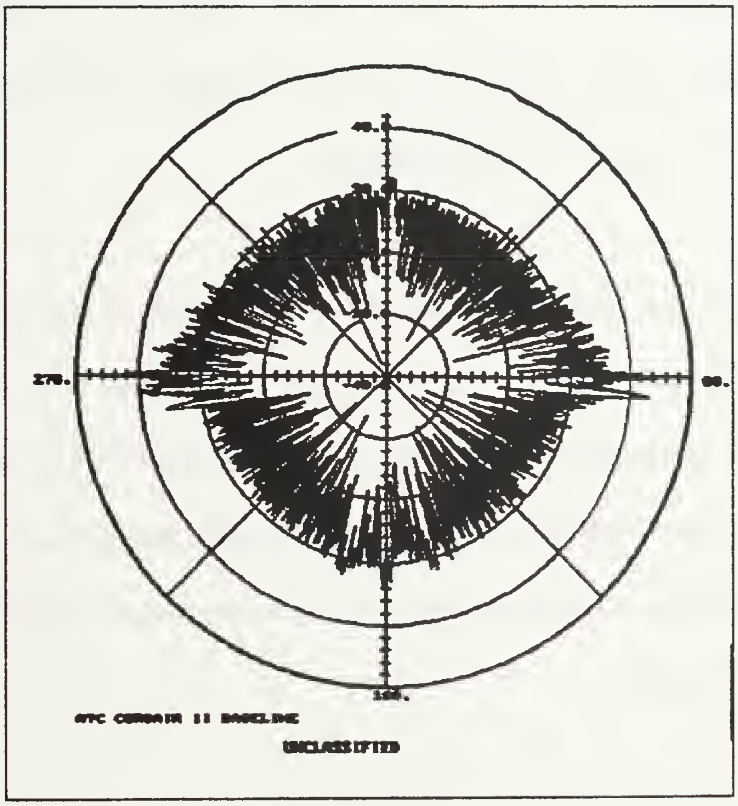


Figure 2. Radar Cross Section Example

A more useful form of the of the Radar Range Equation incorporates a signal to noise ratio, S/N. No radar system is perfect, and all radar systems encounter a certain level of noise. The larger the signal to noise ratio the less likely the system is to have a false alarm and the more likely it is to detect the target. By dividing both sides of the Radar Range Equation by the noise, N, its effects on the system can be incorporated (this form of the Radar Range Equation is used in Chapter IV).

There are two main types of radar: continuous wave radars and pulse radars. Continuous wave radars are on all of the time (receive and send) and are primarily used for acquisition (long range detection). Pulse radars repeatedly transmit for a certain period of time (known as pulse width) and receive for the rest of the time. Pulse radars are used to track targets. The closer the target, the higher the pulse repetition frequency needs to be in order to track the target [Ref. 6].

Beamwidth is another important concept in the study of radar. Beamwidth refers to how wide the beam is and is measured in degrees or radians. Since the radar power dissipates with angle, radar engineers use a term called the 3-dB beamwidth. When the radar energy drops to half of its original strength (3-dB), that angular location defines the boundary of the beam. The beam width for a circular aperture is given by the following equation [Ref 6: p.136]:

$$\theta_{3dB}=\frac{1.02\,\lambda}{d}$$

Where d is the diameter of the antenna and the results are in radians. Related to the beamwidth is the foot print or spot size at the target location. Since the beamwidth is an angular measure, the closer the target is to the radar, the smaller the spot size. Conversely, the farther away the target is, the larger the spot size. In general, a large spot size is used for detection and a small spot size is used for tracking. In order to cover a specific region, the spots must move. The time it takes for the spot to sweep over the entire region is considered one scan.

III. BASIC ASTRONATICAL PRINCIPLES

The purpose of this section is to provide the reader with a brief overview of orbital mechanics. Satellites can have a wide range of orbits These orbits as well as the satellite's position are described by six classical elements. The first element is the semi major axis, *a*. This is a measure of the size of the orbit. The second orbital element is eccentricity, *e* . Eccentricity defines the shape of the orbit. For example, when *e*=0, the orbit is a circular. When *e* is between 0 and 1, the shape of the orbit is an ellipse. The larger e is, the greater the eccentricity. The third element is the inclination, *i.* Inclination is the angle between the Earth's equator and the satellite's orbit (see Figure 3.).

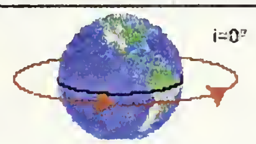
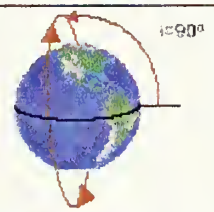
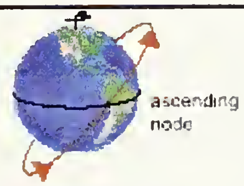
Inclination	**Orbit Type**	**Diagram**
0° = i = 180°	Equatorial	
i = 90°	Polar	
0° ≤ i < 90°	Direct or posigrade (moves in direction of Earth's rotation)	
90° < i ≤ 180°	Indirect or retrograde (moves against the direction of Earth's rotation)	

Figure 3. Inclination Examples, From Ref. [7]

III. BASIC ASTRONAUTICAL PRINCIPLES

The purpose of this section is to provide the reader with a [illegible] orbital mechanics. Satellites can have a wide range of orbits. These orbits [illegible] satellite's position are described by six Classical elements. The fir[illegible] major axis, a. This is a measure of the size of the orbit. The second [illegible] eccentricity, e. Eccentricity defines the shape of the orbit. [illegible] orbit is circular. When e is between 0 and 1, the [illegible] larger e is, the greater the eccentricity. The third [illegible] is the angle between the Earth's equator and the [illegible]

Figure 7. [illegible]

In order to discuss the three other orbital elements, a reference frame needs to be established. Using the standard Cartesian coordinate system, i points toward the vernal equinox, k points north through the center of the Earth, and j is defined by the right hand rule (see Figure 4).

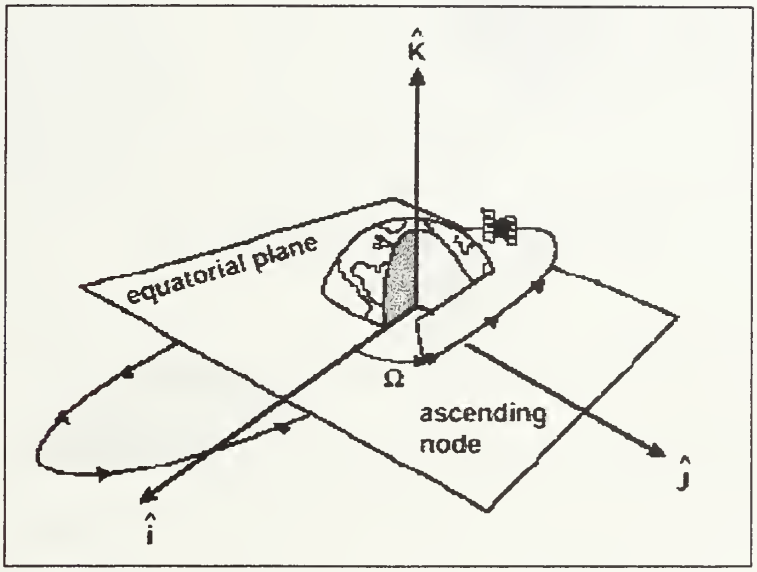


Figure 4. Satellite Coordinate Systems, From Ref. [7].

The fourth element, the Right assention of the ascending node (RAAN or Ω), is the angle between the i direction and the ascending node. The ascending node is the point where the satellite crosses the equatorial plane (moving south to north). The fifth element is the argument of perigee, ω. The argument of perigee is the angular sweep from the ascending node to perigee. Perigee is the point in the orbit where the satellite is the

closest to the Earth (apogee is the farthest point). The true anomaly, υ, is the angular location of the satellite from perigee. Figure 5. Shows a planer view of the orbit.

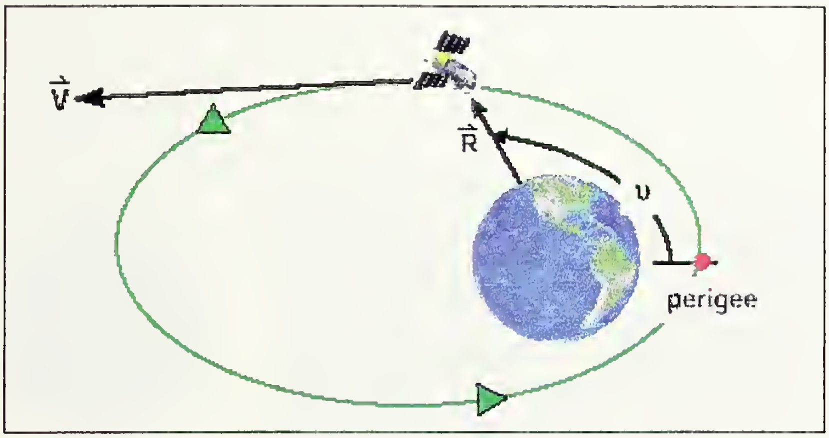


Figure 5. True Anomaly, From Ref. [7].

Another important aspect in understanding satellite orbits is their projection onto the Earth's surface. The projections are know as a ground tracks. Figure 6. shows a sample orbit around the Earth (note that the Earth is not spinning). Projection of the orbit onto a flat map yields a periodic track.

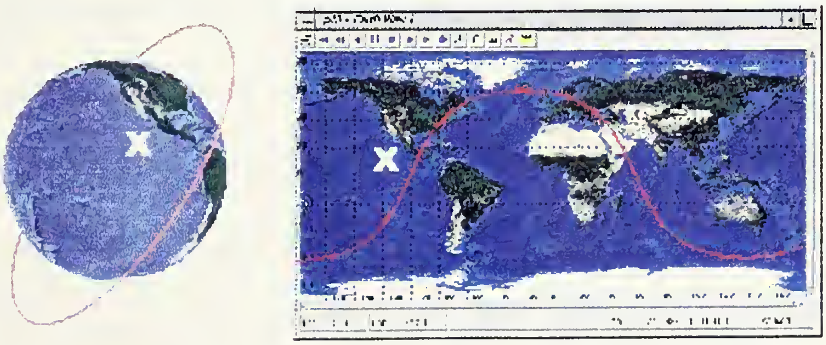


Figure 6. Ground Track, From Ref. [7]

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Figure 5. True Anomaly, From Ref. [7]

Another important aspect to understanding satellite orbits is their projection onto the Earth's surface. The projections are known as a ground tracks. Figure 6. shows a sample orbit across the Earth (note that the Earth is not spherical). Figure 6. shows what occurs as the orbit yields a particular track.

Figure 6. Ground Track, From Ref. [7]

Since the Earth actually spins while the satellite rotates in its orbit, the ground track will move over the surface of the Earth. Figure 7. shows what the first and second orbital passes would look like.

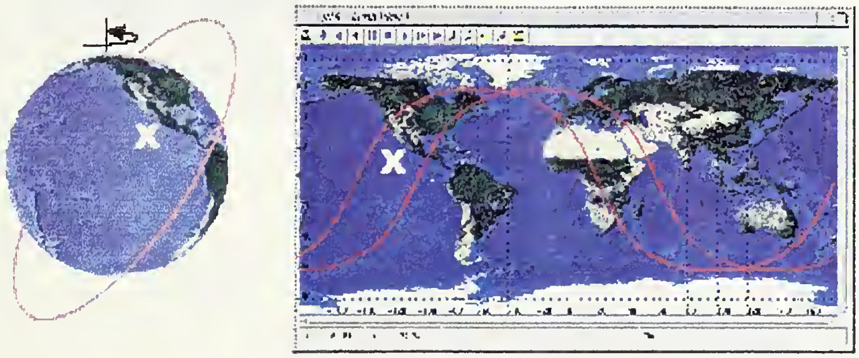

Figure 7. Rotating Earth Ground Track, From Ref. [7]

The lower the orbit (smaller period), the more ground tracks over time. The larger the orbit (larger period) the fewer ground tracks over time. Figure 8. shows the ground tracks for various orbits. At an altitude of 35,786 km a satellite with zero degree inclination will have the same rotation rate as the Earth (24 hr period) and there will be no ground track, only a single point (see Figure 8, item E). This is known as a geosynchronous orbit. Item A has a period of 2.67 hours. Items B, C, and D have corresponding periods of 8 hrs, 18 hrs, and 24 hrs.

Since the Earth actually spins while the satellite orbits at altitude, the ground track will move over the surface of the Earth. Figure 7. shows what the first and second orbital passes would look like.

Figure 7. Rotating Earth Ground Track, From Ref. [1]

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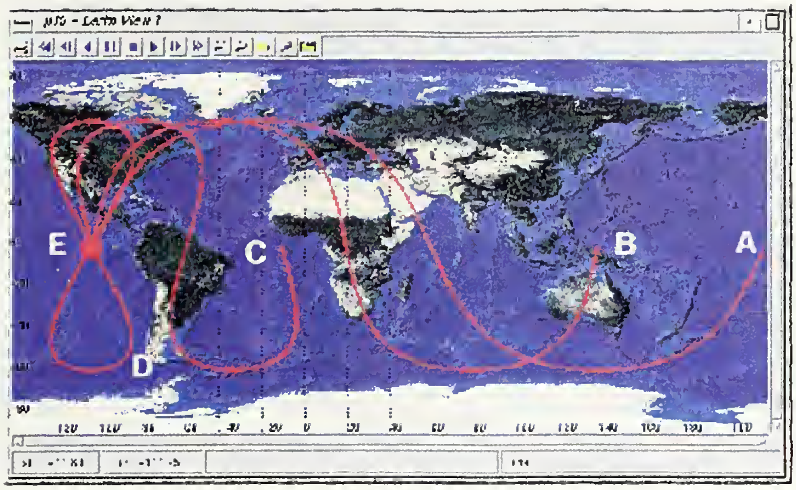

Figure 8. Ground Tracks, From Ref. [7].

IV. SPACE BASED RADAR THREAT

The purpose of this section is to determine whether it is feasible to use space based radar to detect stealth aircraft from space. Two different scenarios have been developed to determine if a space based radar can be used to pick up aircraft targets that have not been treated on the upper surface. The hypothetical threat was chosen to be Iraq (see Figure 9).

Figure 9. Iraq, From Ref. [8]

The two extremes, geosynchronous orbit and low earth orbit, were chosen for analysis purposes. There are an infinite number of orbits that could provide satellite coverage and years could be spent creating the optimal satellite configuration. The goal of the analysis is to show what problems would be encountered at each end of the spectrum and determine if there are solutions.

A. GEOSYNCHRONOUS ORBIT

The first scenario involves a satellite in geosynchronous orbit. From this vantage point the satellite rotates around the earth at the same rate as the Earth's rotation. This allows the satellite to see the same geographic location at all times. Figure 10. shows a satellite in geosynchronous orbit with its antenna pointed at Iraq. Figure 11. shows a blow up of the same view (viewing angle changed for increased clarity).

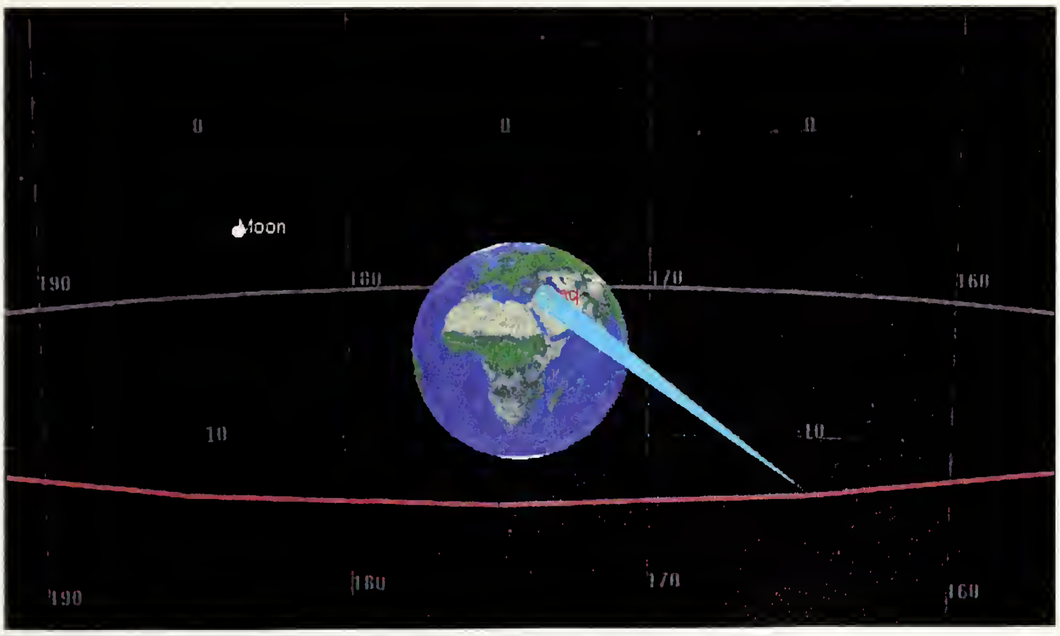

Figure 10. Geostationary Satellite, Ref. [9]

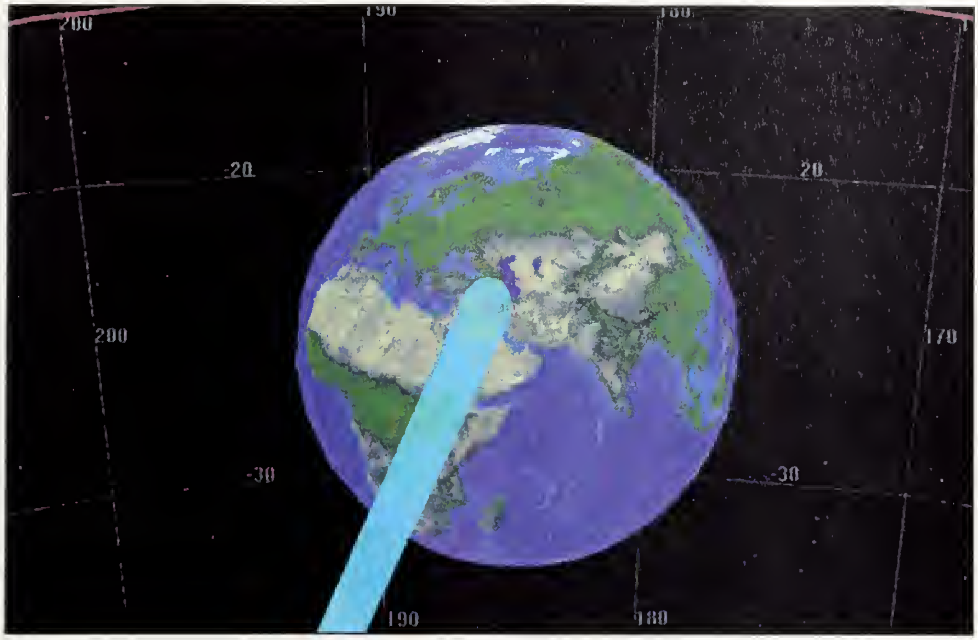

Figure 11. Zoom in, Ref. [9]

Note there is no ground track because relative to the earth there is no satellite motion (see Figure 12.).

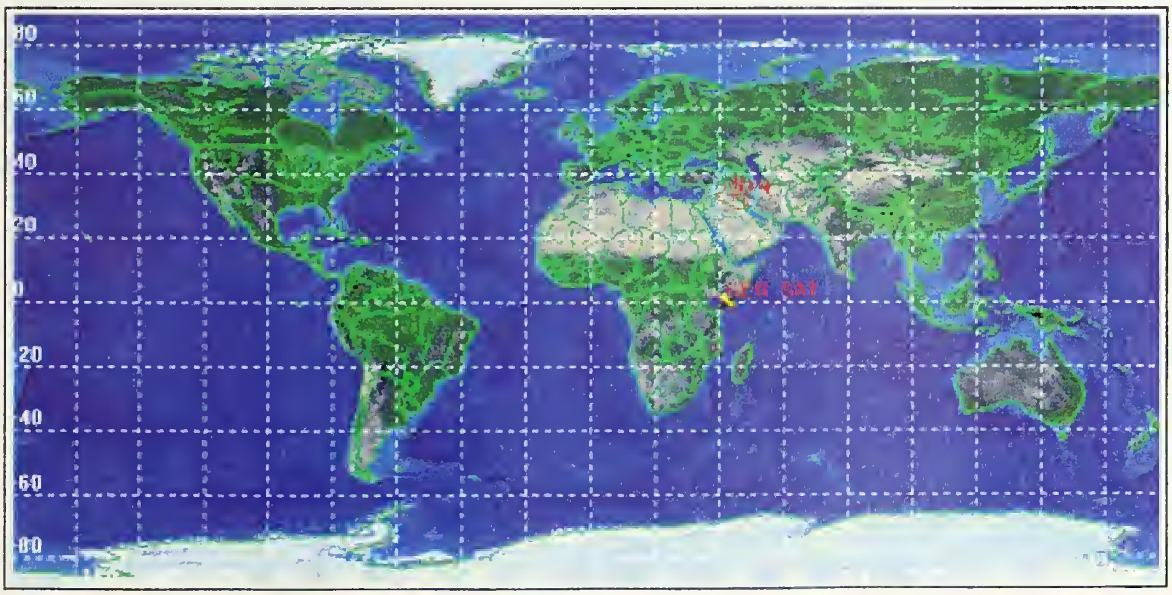

Figure 12. Ground Track

Figure 11. Zoom in, Ref. [9]

Note there is no azimuth track becoming relative to the earth since at the camera (Figure 12.)

Figure 12. Lateral View

The next two figures show a blow up over Iraq (Figures 13 and 14).

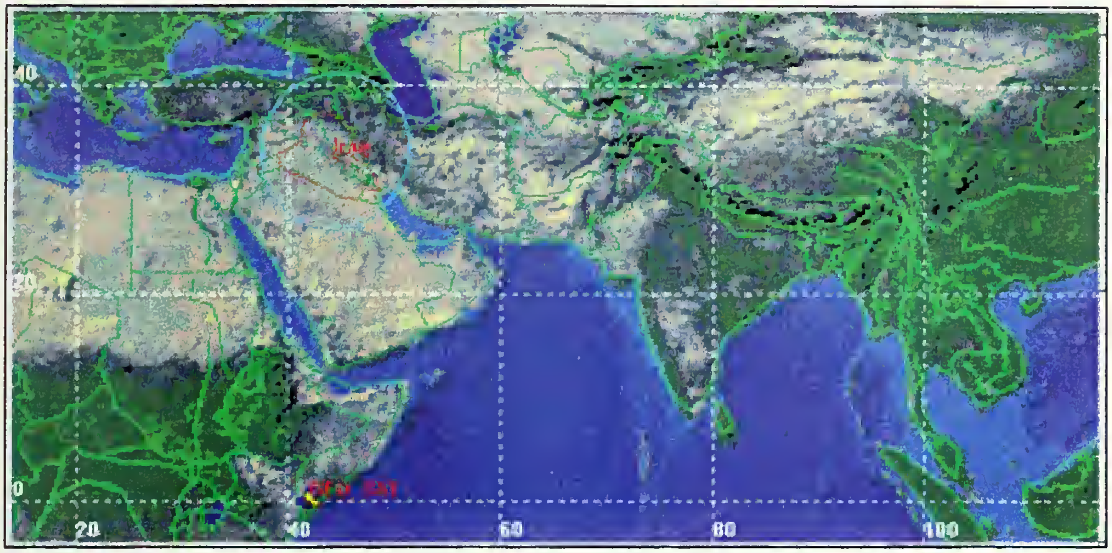

Figure 13. Zoom in on Iraq, Ref. [9].

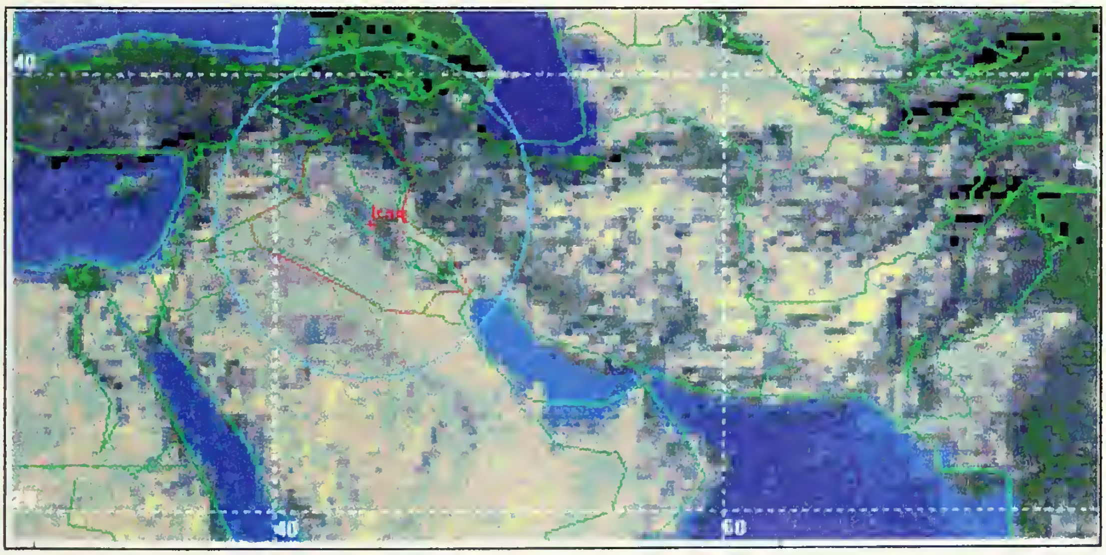

Figure 14. Larger Zoom in on Iraq, Ref. [9].

The [illegible] (Figures 13 and 14).

Figure 13. Zoom in on ring, Ref. [illegible]

Figure 14. [illegible]

The times that the satellite has access to Iraq is summed up in Figure 13. Only one day is represented in the figure, but the coverage would be the same for each successive day.

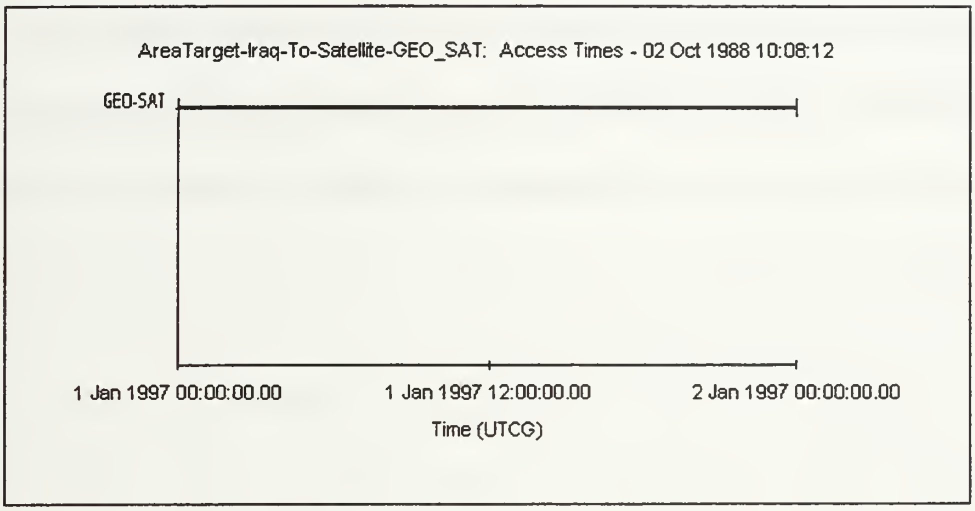

Figure 13. GEO Access Times

While having the advantage of being able to see the same area all the time, being in geosynchronous orbit poses a few technical challenges. The satellite is 35,786 km above the Earth's surface. The first challenge is to determine if a satellite with enough power for detection can be put in this type of orbit. We will use the radar range equation listed below to determine the power requirements of the satellite [Ref. 10:p. 49].

$$P_t = \frac{S(4\pi)^3 R^4 kTB_n}{NG^2\lambda^2\sigma}$$

For analysis purposes we are assuming a perfect radar (except for noise). P_t is the power needed to transmit, S/N is the signal to noise ratio, R is the range (35,786 km in

geosynchronous orbit), k is Boltzmann's constant (1.38×10^{-23} watt-second/°K), T is temperature (°K), B_n is the bandwidth, G is the antenna gain, λ is the wave length, and σ is the signature of the target. For analysis purposes we wish to have a probability of detection of at least 90%. Figure 14. shows the relation between probability of detection and the required S/N ratio (for the given false alarm rate). Case I is for a scan to scan S/N ratio for an airplane type target and Case II is for a pulse to pulse S/N ratio for an airplane type target. Using Case II, a 90% probability of detection corresponds to a S/N ratio of 15.2 dB.

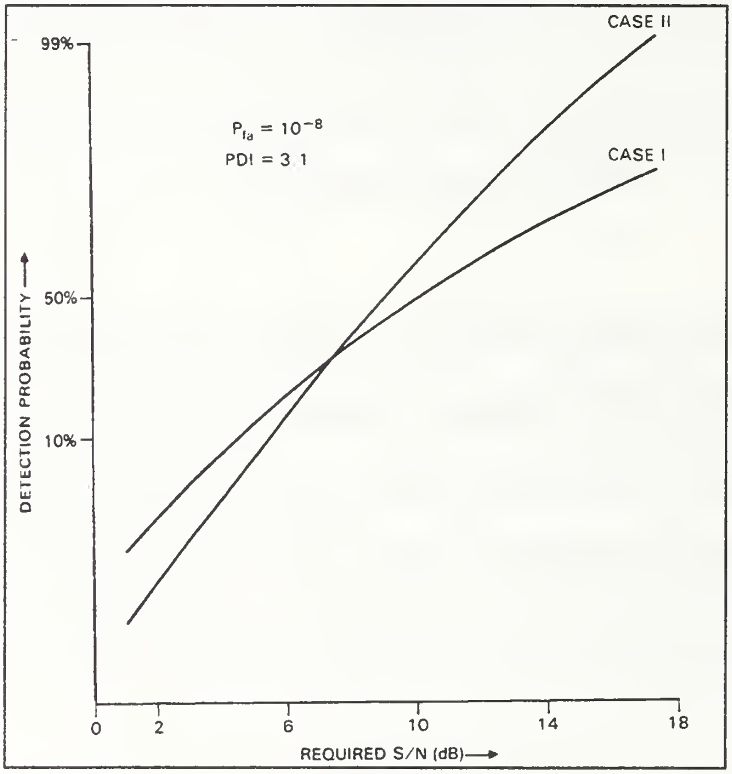

Figure 14. Signal to Noise vs. Detection Probability, From Ref. [6].

The antenna noise temperature for 1 GHz is about 70 °K [Ref. 11 and 12]. Lastly, the bandwidth is a function of the pulse width (B_n=2/pulse width, measured Hz) [Ref. 6: p. 259].

An acquisition radar usually has its radar on for extended periods of time (continuous wave radars). However, for space based radar the background clutter of the earth needs to be filtered out. This is done by pulsing the radar. From geosynchronous orbit it takes the radar pulses 0.23857 seconds to reach the earth and bounce back (assuming a uniform spherical earth; the numbers would vary form location to location, i.e. mountainous terrain). Any return that is received before 0.23857 seconds is a possible aircraft. In order to keep the pulses from overlapping the echoes, the pulses must be spaced at least 0.2386 seconds apart, plus the pulse width time. For the acquisition case, the pulse width was chosen to be 1 second (the larger the pulse width, the less power required). For tracking, the pulse repetition frequency needs to be around 0.001 seconds or smaller and the pulse width should be on the same order or smaller [Ref. 6]. A pulse width of 0.001 seconds will be used in the tracking scenario.

One important feature of the geosynchronous radar is the very small difference in range between the target and the background clutter (the Earth). A fighter aircraft flying at an altitude of 3,048 meters (10,000 feet) would be 35,782,952 meters from the satellite. At this distance, the satellite would receive a signal from the target 0.23855 seconds after it was sent, only 0.00002 seconds faster than the clutter return from the ground. Current software and signal processing technologies can be used to discriminate

the difference (examples are pulse modulation and pulse compression: For detailed discussions on ways to solve the ground clutter problem, the reader is referred to the references 13, 14, 15 and 16).

The gain for a parabolic reflector is given below [Ref. 6].

$$G=\frac{(\pi D)^2}{\lambda^2}$$

The parabolic antenna is assumed to have a diameter of 20 meters (perfectly feasible in space). In order to minimize atmospheric losses, a frequency of 1 GHz was selected. See Figures 15. and 16. for plots of atmospheric loss verses frequency.

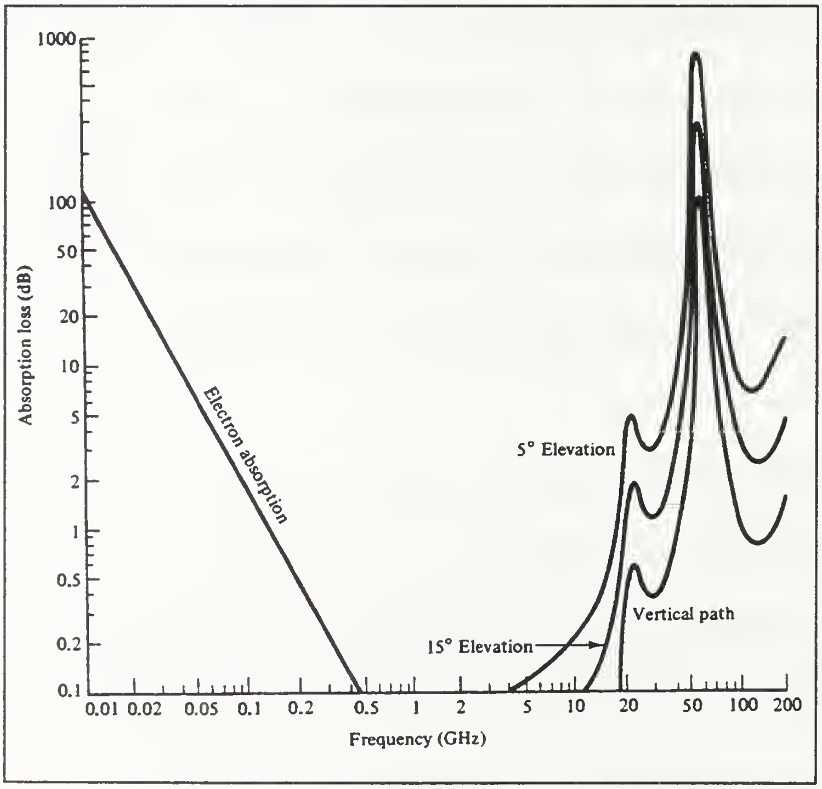

Figure 15. Atmospheric Losses 1, From Ref. [11]

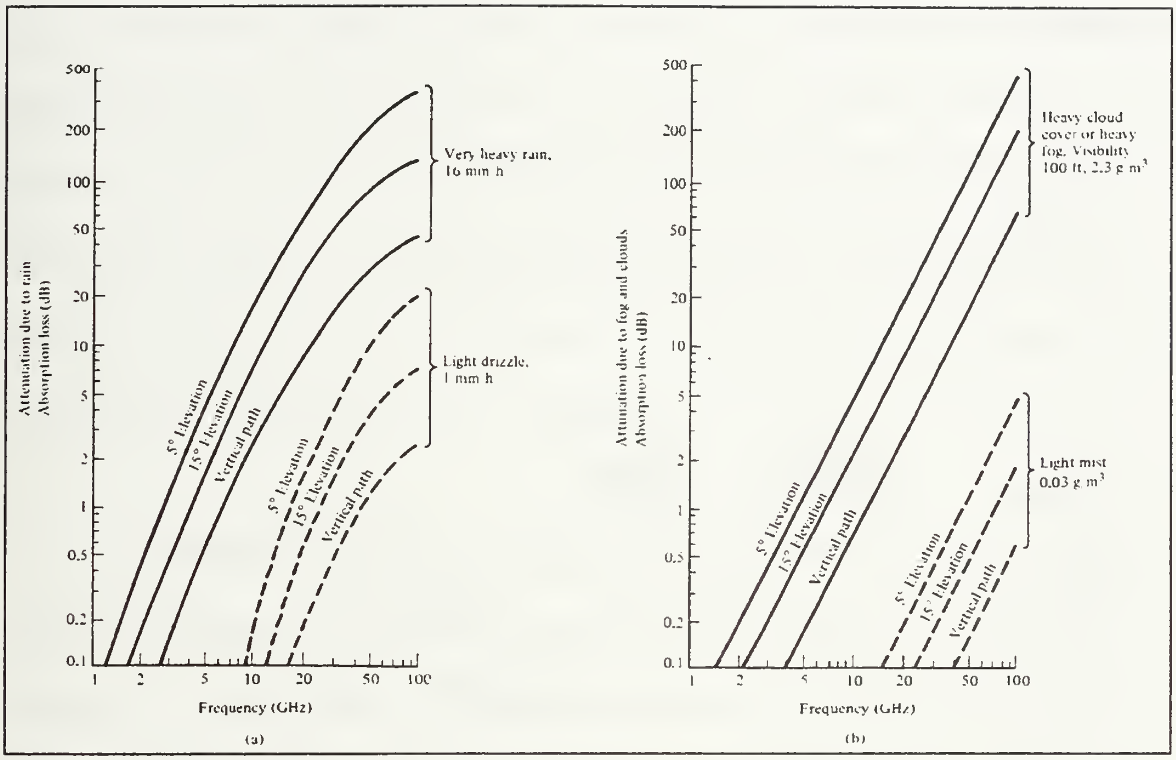

Figure 15. Atmospheric Losses 2, From Ref. [11]

The upper surface of the aircraft is assumed to have a signature of 100 m^2, a very reasonable assumption.

Based on the aforementioned assumptions and the equations in this Chapter, the satellite would need to have about 12 kW of power for a 90% chance of detecting the target. If we extrapolate the data given in figure 16., the power available in 1997 would be about 5 kW. The power improvements over time are due to increased efficiency of the solar cells, an increase in solar array size, and improved battery performance. Even with

the power improvements, there is still not enough power required to detect the target. Even more power would be required to track the target (12,000 kW) due to the lower pulse repetition frequency.

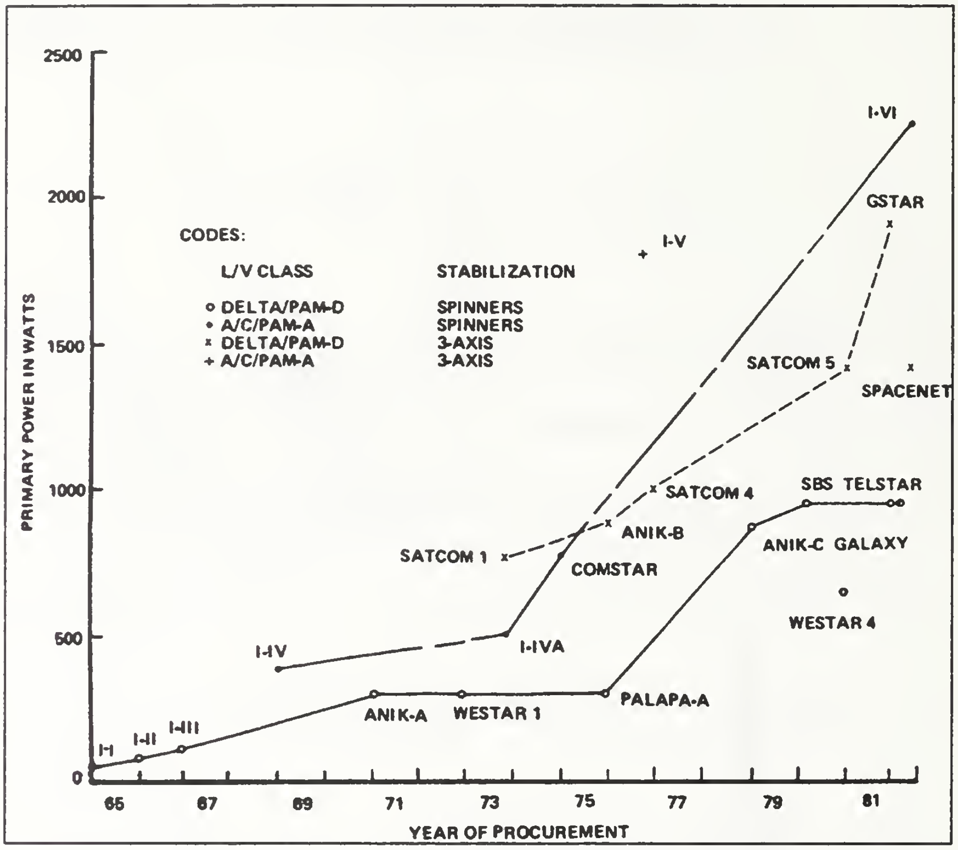

Figure 16. Satellite Power , From Ref. [11]

To reduce the power requirement, instead of having a single pulse probability of detection of 90%, a cumulative probability of detection of 90% could be specified. The formula for the cumulative probability of detection is given below [Ref. 6].

$$P_c=1-(1-P_d)^n$$

P_c is the cumulative probability of detection, P_d is the single scan probability of detection, and n is the number of scans. By lowering the probability of detection to 37.5% (S/N=8 dB) and performing 5 scans (equivalent to 6.2 seconds), a cumulative probability of detection of 90.4% is obtained. This results in a power requirement of 2.3 kW, well within reason. When the cumulative probability of detection is applied to the tracking scenario, power requirements are still unrealistic (2,290 kW) and the time delay would make active tracking unrealistic.

The spot size for this particular scenario has a diameter of 548 km and covers an area of 235,858 km^2. Since Iraq has a square area of 441,839 km^2, a rough approximation would indicate that the spot would have to be moved twice to cover the entire area. Even if enough power were available for tracking, the spot size would be too large to track the target.

Solutions to the power problem are forthcoming. The Air Force's Phillips Laboratory is currently working on developing a satellite system that can develop 20 kW of continuos power and 50 kW of peak power [Ref. 17:p. 57]. The Air Force is also working on "flexible blanket" solar arrays that can provide 150 kW per kilogram [Ref. 17:p 57]. Another possible solution to the power problem is a bi-static system. A larger transmitting antenna could be placed on earth and the satellite would only need to receive the signals (drastically reducing satellite power requirements). Bi-static systems are very complex in nature and well beyond the scope of this thesis.

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B. LOW EARTH ORBIT

The second scenario involves using satellites in low earth orbit (LEO) to track aircraft targets. By placing a satellite in low earth orbit the distance problem is solved (GEO is at 35,786 km and the power required is a function of R^4), but it creates new technical challenges. In LEO, the satellite does not rotate at the same rate as the Earth, hence one satellite can not see the same location at all times. The closer the satellite is to the Earth, the more satellites you need to provide continuous coverage. For this scenario an altitude of 1000 km was chosen.

In order to provide continuous coverage at an altitude of 1000 km, 32 satellites are needed. The satellites are placed in eight, 90° inclined, orbits with right assention of the ascending node values of 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 325°. Each orbit contains 4 equally spaced satellites (true anomalies of 0°,90°,180° and 270°). Figure 17. shows the orbits with Iraq once again being the target area.

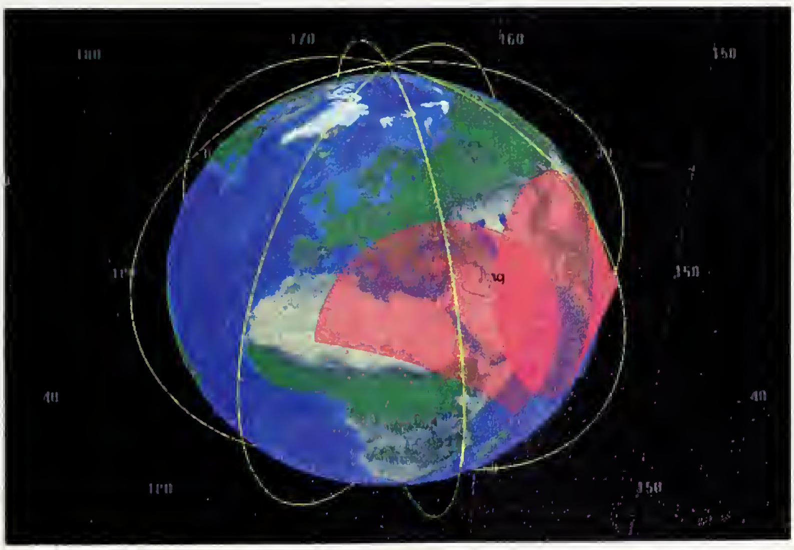


Figure 17. LEO Access, Ref. [9]

Figure 18. shows a blow up of the ground tracks and the area of coverage. Note that there are so many ground tracks that if we zoomed out (entire Earth view) the entire picture would be yellow with ground tracks.

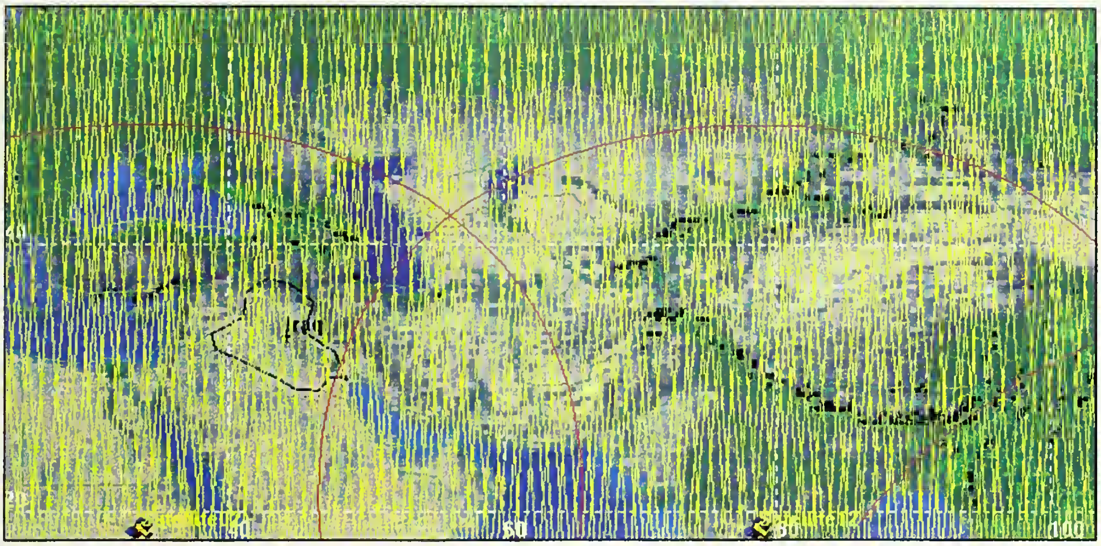


Figure 18. Iraq Coverage, Ref. [9]

To improve picture clarity, figure 19 show the same area with the ground tracks removed.

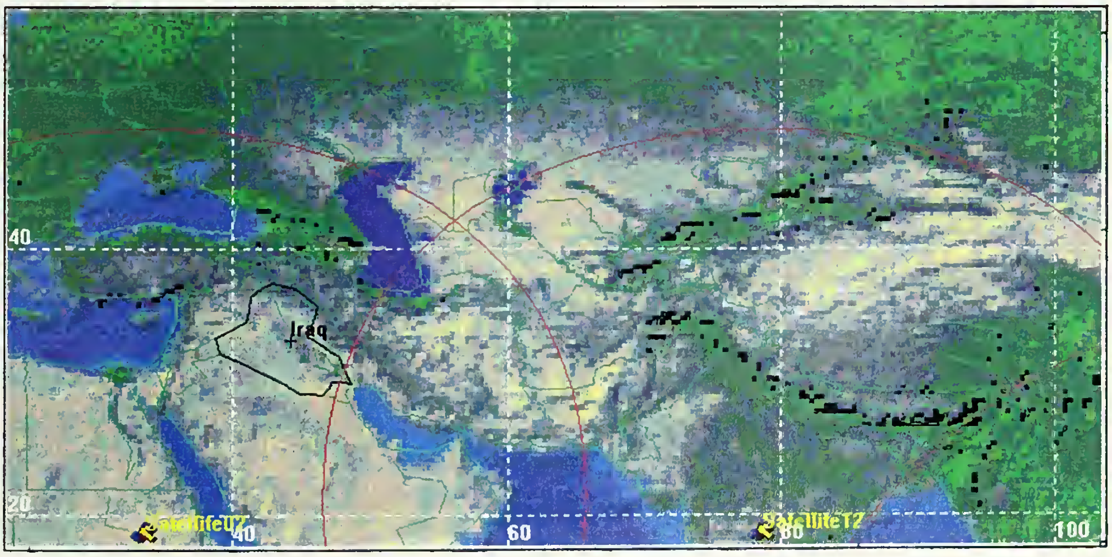


Figure 19. Iraq with Ground Tracks Removed, Ref. [9]

Figure 15. shows a blow up of the ground truth and the area of coverage. Note that there are so many ground truths that if we selected all [illegible] there the entire picture would be yellow with ground truths.

Figure 18. Iraq Coverage, Ref. [9]

To improve pictorial clarity, figure 19 show the same area with [illegible]

Figure 19. Iraq with Reduced Truth Data (Ref. [9])

The access times between the satellites and Iraq are summed up in figure 20 (a detailed list of access times is listed the Appendix).

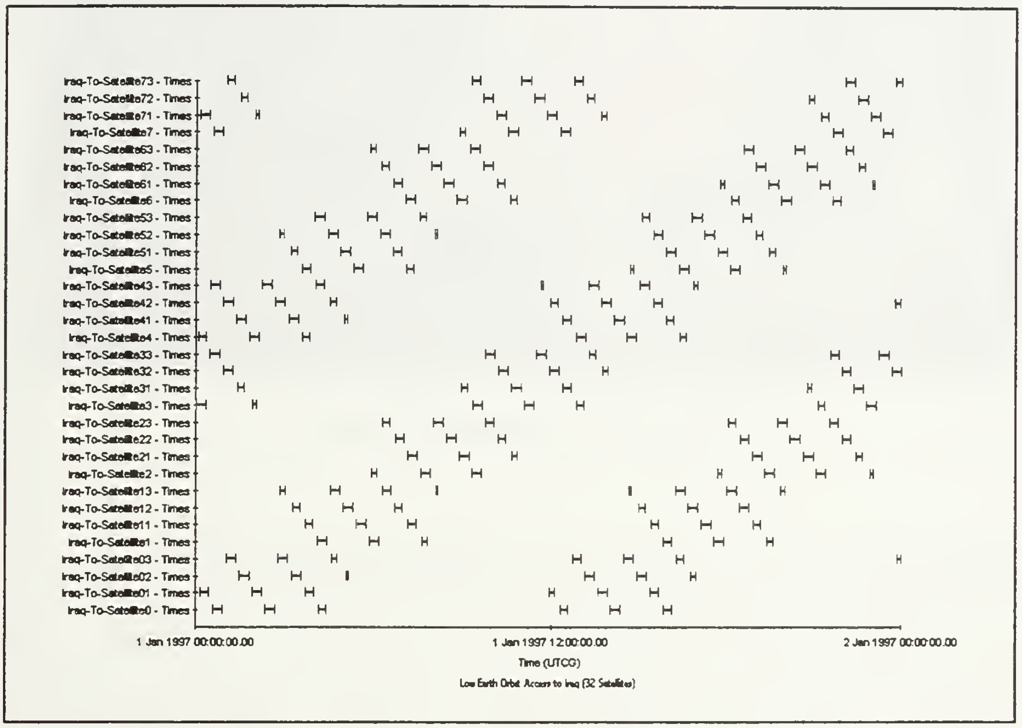


Figure 20. LEO Access times to Iraq, Ref. [9].

It should be mentioned that there are certain instances where the target area can be covered by more than one satellite (see Figure 21). Further orbital analysis could be performed to try to reduce the number of satellites (the purpose of this thesis is to evaluate the two extremes, years could be spent trying to find the optimal satellite configuration for a given target area) or the satellites could be configured for a bi-static configuration (again beyond the scope of this thesis).

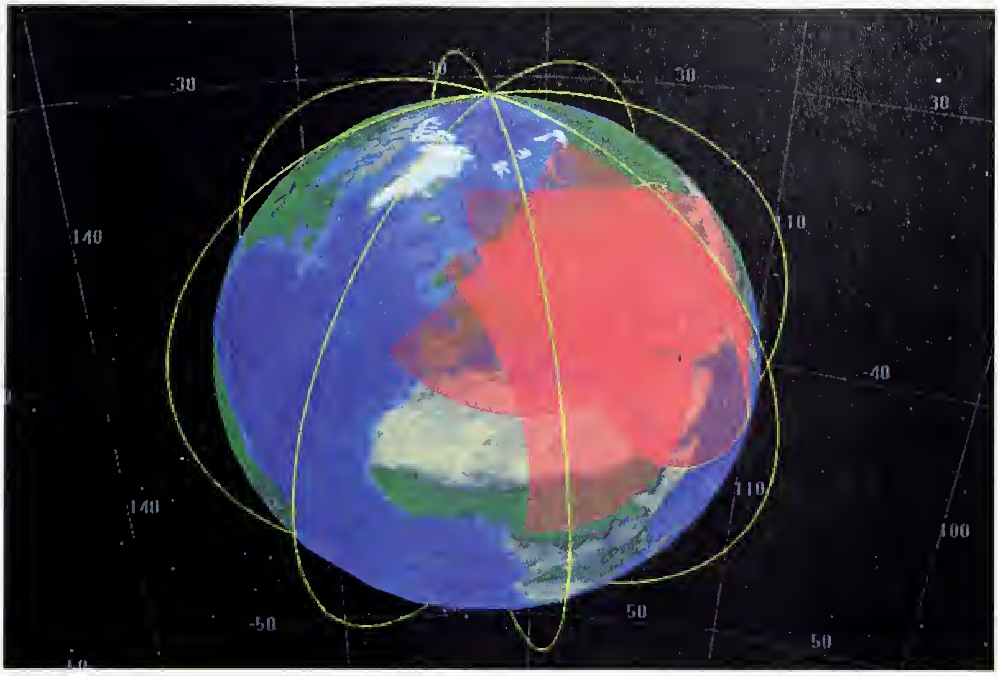


Figure 21. Multiple Access, Ref. [9]

Using the same radar range equation used in section IVa, a single probability of detection of 90%, and a 5 meter antenna, a LEO satellite would only need 0.78 kW of power to detect the target. Using an 8 meter diameter antenna the power needed to track the target (using a pulse width of 0.001 s) is 2.02 kW, again very feasible. The time it takes for the radar signal to reach the Earth and bounce back is 0.0067 seconds. The time it takes to receive the signal from an aircraft flying at an altitude of 10,000 feet is 0.0064 seconds. The time difference is better than GEO, but still very small (0.0003 s). The target can be puled out of the clutter by using modern pulse compression techniques [Ref. 13,14,15,16].

Figure 21. Example Answer, Part [illegible]

Using the Gans radar range equation [illegible]

detection of 90% and a 5 meter accuracy, a 1.0 [illegible]

power to detect the target. Using [illegible]

the target (using a pulse width of 0.005 [illegible]

takes for the radar signal to reach the target and [illegible]

then it takes to receive the signal [illegible]

0.0033 seconds. The time difference [illegible]

The target can be placed [illegible]

[Ref. 17: P. 1-24].

The spot sizes for the 5 meter and 8 meter dishes have diameters 61 km and 38 km respectively. This corresponds to square areas of 2922 km^2 and 1134 km^2. Again, noting that Iraq has a square area of 441,839 km^2 and using a rough approximation, it would take the 5 meter dish 390 spots or about 3 seconds to complete one scan of the area. For the 8 meter dish it would take about 151 spots or about 1.2 seconds for one scan of the area. A LEO satellite constellation poses a real threat to the US's stealth aircraft.

V. CONCLUSIONS

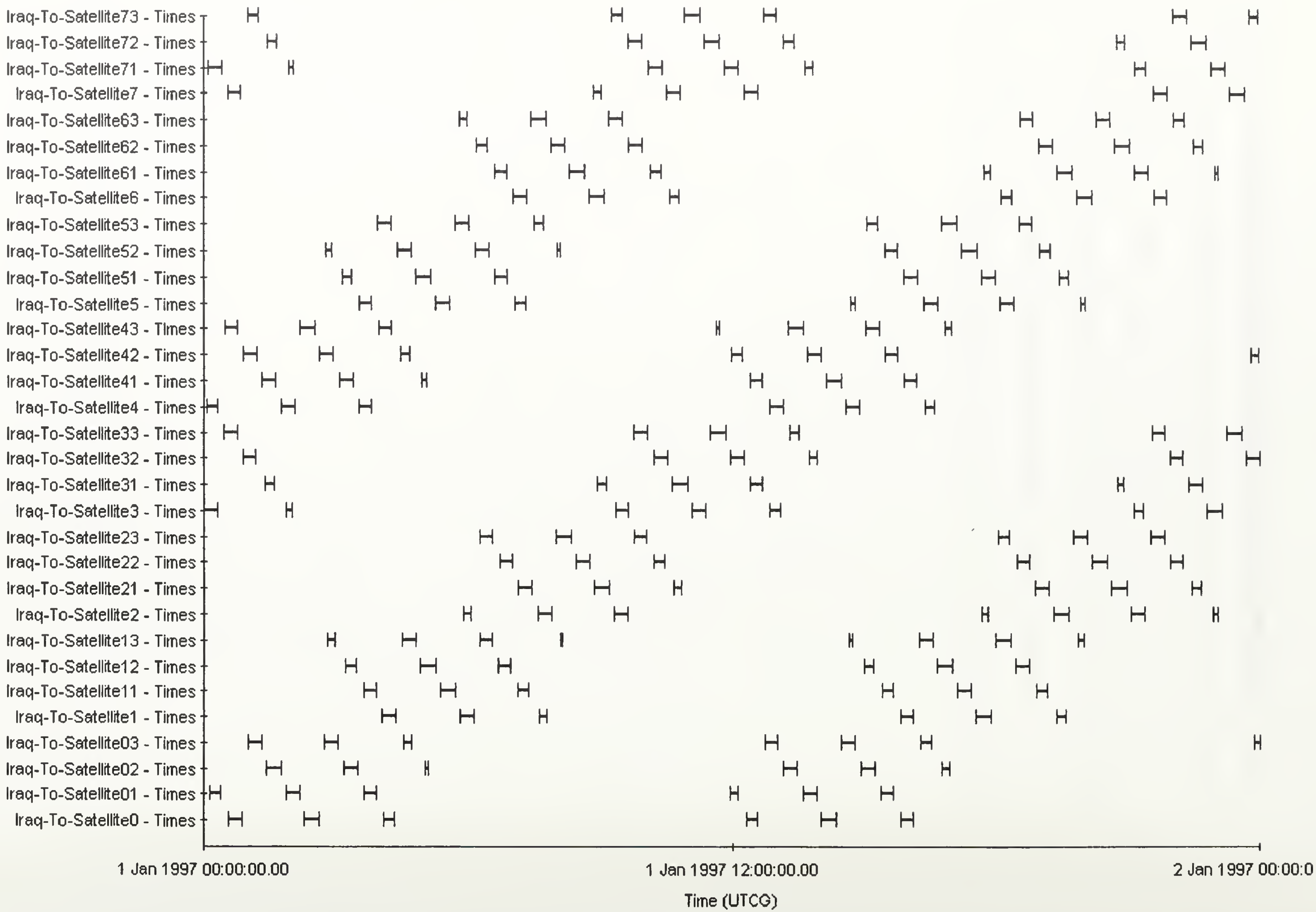
Based on the analysis and simplified assumptions, future space-based radar systems may pose a significant threat to current stealth technology design trends. Although challenging, using today's technology, a satellite in GEO can detect aircraft targets on the earth. Because of the large power requirements and spot size, this type of systems would only be useful for early warning. Target discrimination would not be possible and therefore it is not yet feasible to track in GEO. However, as power generation and processing techniques improve, this could all change.

A satellite in LEO can both detect and track targets. The tracking rate in LEO is not yet high enough for missile guidance, but it is high enough that a fighter could be given coordinates and vectored to the general area. The number of satellites needed in LEO (32 in the Iraq scenario) might seem excessive and unrealistic, but there are several satellite constellations with the number of satellites ranging from 8 to 66 that will be put into LEO between now and 2002 [Ref. 18]. In the future, advanced satellite systems may be able to detect the target, track the target, and guide missiles close enough for their own internal guidance systems to take over.

The are a few solutions to the problem. The first would be to apply radar absorbing materials to the upper surface of stealth aircraft. This would reduce the aircraft's signature and make it more difficult to detect and track. Another solution is to use jamming. A ground or space-based system could be set up to saturate the satellite's

receiving antenna. Going one step farther, the satellites could be destroyed before the aircraft are sent into a hostile area. This of course would go against the International agreement for non aggression in space [Ref. 19]. However, as this thesis is being written, the Air Force is currently waiting for approval to fire one of it high powered, ground based lasers at one of its own (old and dying) satellites to see how badly it would be damaged [Ref. 20]. The wars in the future are going to get a lot more complicated.

APPENDIX-LEO ACCESS TIMES TO IRAQ



Low Earth Orbit Access to Iraq (32 Satellites)

02 Oct 1988 08:28:45

AreaTarget-Iraq-To-Satellite-Satellite0, Satellite-Satellite01, Satellite-Satellite02, Satellite-Satellite03, Satellite-Satellite1, Satellite-Satellite11, Satellite-Satellite12, Satellite-Satellite13, Satellite-Satellite2, Satellite-Satellite21, Satellite-Satellite22, Satellite-Satellite23, Satellite-Satellite3, Satellite-Satellite31, Satellite-Satellite32, Satellite-Satellite33, Satellite-Satellite4, Satellite-Satellite41, Satellite-Satellite42, Satellite-Satellite43, Satellite-Satellite5, Satellite-Satellite51, Satellite-Satellite52, Satellite-Satellite53, Satellite-Satellite6, Satellite-Satellite61, Satellite-Satellite62, Satellite-Satellite63, Satellite-Satellite7, Satellite-Satellite71, Satellite-Satellite72, Satellite-Satellite73: Access Summary Report

Iraq-To-Satellite0 - Access	Iraq-To-Satellite0 - Start Time (UTCG)	Iraq-To-Satellite0 - Stop Time (UTCG)	Iraq-To-Satellite0 - Duration (sec)
1	1 Jan 1997 00:34:15.80	1 Jan 1997 00:51:13.86	1018.061
2	1 Jan 1997 02:18:04.50	1 Jan 1997 02:38:03.15	1198.644
3	1 Jan 1997 04:04:27.67	1 Jan 1997 04:19:29.94	902.276
4	1 Jan 1997 12:19:51.28	1 Jan 1997 12:35:09.66	918.383
5	1 Jan 1997 14:01:36.63	1 Jan 1997 14:21:45.13	1208.508
6	1 Jan 1997 15:49:12.43	1 Jan 1997 16:05:45.21	992.775

Global Statistics

Min Iraq-To-Satellite0 - Duration	3	1 Jan 1997 04:04:27.67	1 Jan 1997 04:19:29.94	902.276
Max Iraq-To-Satellite0 - Duration	5	1 Jan 1997 14:01:36.63	1 Jan 1997 14:21:45.13	1208.508
Mean Iraq-To-Satellite0 - Duration			1039.774	
Total Iraq-To-Satellite0 - Duration			6238.646	

Iraq-To-Satellite01 - Access	Iraq-To-Satellite01 - Start Time (UTCG)	Iraq-To-Satellite01 - Stop Time (UTCG)	Iraq-To-Satellite01 - Duration (sec)
1	1 Jan 1997 00:09:03.72	1 Jan 1997 00:23:16.88	853.160
2	1 Jan 1997 01:51:52.08	1 Jan 1997 02:11:54.81	1202.729
3	1 Jan 1997 03:37:33.23	1 Jan 1997 03:54:38.12	1024.896
4	1 Jan 1997 11:55:57.04	1 Jan 1997 12:07:41.10	704.059
5	1 Jan 1997 13:35:35.42	1 Jan 1997 13:55:21.94	1186.527
6	1 Jan 1997 15:21:53.55	1 Jan 1997 15:40:03.37	1089.826

Global Statistics

Min Iraq-To-Satellite01 - Duration	4	1 Jan 1997 11:55:57.04	1 Jan 1997 12:07:41.10	704.059
Max Iraq-To-Satellite01 - Duration	2	1 Jan 1997 01:51:52.08	1 Jan 1997 02:11:54.81	1202.729
Mean Iraq-To-Satellite01 - Duration				1010.200
Total Iraq-To-Satellite01 - Duration				6061.197

Iraq-To-Satellite02 - Access	Iraq-To-Satellite02 - Start Time (UTCG)	Iraq-To-Satellite02 - Stop Time (UTCG)	Iraq-To-Satellite02 - Duration (sec)
1	1 Jan 1997 01:25:48.52	1 Jan 1997 01:45:25.74	1177.225
2	1 Jan 1997 03:10:53.92	1 Jan 1997 03:29:17.23	1103.303
3	1 Jan 1997 05:00:51.94	1 Jan 1997 05:06:09.55	317.605
4	1 Jan 1997 13:09:57.64	1 Jan 1997 13:28:49.86	1132.223
5	1 Jan 1997 14:54:43.00	1 Jan 1997 15:14:06.96	1163.960
6	1 Jan 1997 16:46:11.60	1 Jan 1997 16:55:16.12	544.528

Global Statistics

Min Iraq-To-Satellite02 - Duration	3	1 Jan 1997 05:00:51.94	1 Jan 1997 05:06:09.55	317.605
Max Iraq-To-Satellite02 - Duration	1	1 Jan 1997 01:25:48.52	1 Jan 1997 01:45:25.74	1177.225
Mean Iraq-To-Satellite02 - Duration				906.474
Total Iraq-To-Satellite02 - Duration				5438.844

Iraq-To-Satellite03 - Access	Iraq-To-Satellite03 - Start Time (UTCG)	Iraq-To-Satellite03 - Stop Time (UTCG)	Iraq-To-Satellite03 - Duration (sec)
1	1 Jan 1997 00:59:55.54	1 Jan 1997 01:18:31.04	1115.497
2	1 Jan 1997 02:44:24.99	1 Jan 1997 03:03:51.38	1166.397
3	1 Jan 1997 04:31:50.75	1 Jan 1997 04:43:35.94	705.192
4	1 Jan 1997 12:44:37.99	1 Jan 1997 13:02:06.56	1048.569
5	1 Jan 1997 14:28:00.19	1 Jan 1997 14:48:00.27	1200.082
6	1 Jan 1997 16:17:05.35	1 Jan 1997 16:31:01.50	836.142

7	1 Jan 1997 23:50:57.58	2 Jan 1997 00:00:00.00	542.425

Global Statistics

Min Iraq-To-Satellite03 - Duration	7	1 Jan 1997 23:50:57.58	2 Jan 1997 00:00:00.00	542.425
Max Iraq-To-Satellite03 - Duration	5	1 Jan 1997 14:28:00.19	1 Jan 1997 14:48:00.27	1200.082
Mean Iraq-To-Satellite03 - Duration			944.900	
Total Iraq-To-Satellite03 - Duration			6614.302	

Iraq-To-Satellite1 - Access	Iraq-To-Satellite1 - Start Time (UTCG)	Iraq-To-Satellite1 - Stop Time (UTCG)	Iraq-To-Satellite1 - Duration (sec)
1	1 Jan 1997 04:04:00.99	1 Jan 1997 04:22:50.03	1129.044
2	1 Jan 1997 05:48:36.64	1 Jan 1997 06:07:53.93	1157.298
3	1 Jan 1997 07:36:18.15	1 Jan 1997 07:47:16.39	658.244
4	1 Jan 1997 15:48:35.91	1 Jan 1997 16:06:22.40	1066.492
5	1 Jan 1997 17:32:13.15	1 Jan 1997 17:52:09.27	1196.117
6	1 Jan 1997 19:21:38.49	1 Jan 1997 19:34:56.01	797.517

Global Statistics

Min Iraq-To-Satellite1 - Duration	3	1 Jan 1997 07:36:18.15	1 Jan 1997 07:47:16.39	658.244
Max Iraq-To-Satellite1 - Duration	5	1 Jan 1997 17:32:13.15	1 Jan 1997 17:52:09.27	1196.117
Mean Iraq-To-Satellite1 - Duration			1000.785	
Total Iraq-To-Satellite1 - Duration			6004.712	

Iraq-To-Satellite11 - Access	Iraq-To-Satellite11 - Start Time (UTCG)	Iraq-To-Satellite11 - Stop Time (UTCG)	Iraq-To-Satellite11 - Duration (sec)
1	1 Jan 1997 03:38:18.09	1 Jan 1997 03:55:36.94	1038.854
2	1 Jan 1997 05:22:14.76	1 Jan 1997 05:42:10.00	1195.237
3	1 Jan 1997 07:08:46.66	1 Jan 1997 07:23:21.05	874.395
4	1 Jan 1997 15:23:42.49	1 Jan 1997 15:39:28.73	946.241
5	1 Jan 1997 17:05:46.44	1 Jan 1997 17:25:55.60	1209.157

6	1 Jan 1997 18:53:36.35	1 Jan 1997 19:09:46.85	970.491

Global Statistics

Min Iraq-To-Satellite11 - Duration	3	1 Jan 1997 07:08:46.66	1 Jan 1997 07:23:21.05	874.395
Max Iraq-To-Satellite11 - Duration	5	1 Jan 1997 17:05:46.44	1 Jan 1997 17:25:55.60	1209.157
Mean Iraq-To-Satellite11 - Duration				1039.062
Total Iraq-To-Satellite11 - Duration				6234.375

Iraq-To-Satellite12 - Access	Iraq-To-Satellite12 - Start Time (UTCG)	Iraq-To-Satellite12 - Stop Time (UTCG)	Iraq-To-Satellite12 - Duration (sec)
1	1 Jan 1997 03:12:59.53	1 Jan 1997 03:27:48.90	889.374
2	1 Jan 1997 04:56:00.92	1 Jan 1997 05:16:04.71	1203.794
3	1 Jan 1997 06:41:48.64	1 Jan 1997 06:58:35.75	1007.106
4	1 Jan 1997 14:59:36.03	1 Jan 1997 15:12:08.24	752.208
5	1 Jan 1997 16:39:41.14	1 Jan 1997 16:59:33.90	1192.760
6	1 Jan 1997 18:26:14.62	1 Jan 1997 18:44:08.48	1073.854

Global Statistics

Min Iraq-To-Satellite12 - Duration	4	1 Jan 1997 14:59:36.03	1 Jan 1997 15:12:08.24	752.208
Max Iraq-To-Satellite12 - Duration	2	1 Jan 1997 04:56:00.92	1 Jan 1997 05:16:04.71	1203.794
Mean Iraq-To-Satellite12 - Duration				1019.849
Total Iraq-To-Satellite12 - Duration				6119.096

Iraq-To-Satellite13 - Access	Iraq-To-Satellite13 - Start Time (UTCG)	Iraq-To-Satellite13 - Stop Time (UTCG)	Iraq-To-Satellite13 - Duration (sec)
1	1 Jan 1997 02:48:45.16	1 Jan 1997 02:58:48.50	603.341
2	1 Jan 1997 04:29:55.71	1 Jan 1997 04:49:39.87	1184.160
3	1 Jan 1997 06:15:07.18	1 Jan 1997 06:33:18.35	1091.166
4	1 Jan 1997 08:06:55.96	1 Jan 1997 08:08:47.23	111.270
5	1 Jan 1997 14:38:01.00	1 Jan 1997 14:43:08.46	307.462

6	1 Jan 1997 16:13:59.52	1 Jan 1997 16:33:03.56	1144.047
7	1 Jan 1997 17:59:00.58	1 Jan 1997 18:18:14.27	1153.693
8	1 Jan 1997 19:51:04.78	1 Jan 1997 19:58:47.00	462.220

Global Statistics

Min Iraq-To-Satellite13 - Duration	4	1 Jan 1997 08:06:55.96	1 Jan 1997 08:08:47.23	111.270
Max Iraq-To-Satellite13 - Duration	2	1 Jan 1997 04:29:55.71	1 Jan 1997 04:49:39.87	1184.160
Mean Iraq-To-Satellite13 - Duration				757.170
Total Iraq-To-Satellite13 - Duration				6057.360

Iraq-To-Satellite2 - Access	Iraq-To-Satellite2 - Start Time (UTCG)	Iraq-To-Satellite2 - Stop Time (UTCG)	Iraq-To-Satellite2 - Duration (sec)
1	1 Jan 1997 05:52:23.30	1 Jan 1997 06:03:36.89	673.593
2	1 Jan 1997 07:34:03.04	1 Jan 1997 07:53:53.07	1190.027
3	1 Jan 1997 09:19:20.66	1 Jan 1997 09:37:19.67	1079.014
4	1 Jan 1997 17:40:41.18	1 Jan 1997 17:48:08.63	447.453
5	1 Jan 1997 19:18:01.49	1 Jan 1997 19:37:16.75	1155.255
6	1 Jan 1997 21:03:18.95	1 Jan 1997 21:22:21.15	1142.202
7	1 Jan 1997 22:56:08.30	1 Jan 1997 23:01:56.09	347.794

Global Statistics

Min Iraq-To-Satellite2 - Duration	7	1 Jan 1997 22:56:08.30	1 Jan 1997 23:01:56.09	347.794
Max Iraq-To-Satellite2 - Duration	2	1 Jan 1997 07:34:03.04	1 Jan 1997 07:53:53.07	1190.027
Mean Iraq-To-Satellite2 - Duration				862.191
Total Iraq-To-Satellite2 - Duration				6035.338

Iraq-To-Satellite21 - Access	Iraq-To-Satellite21 - Start Time (UTCG)	Iraq-To-Satellite21 - Stop Time (UTCG)	Iraq-To-Satellite21 - Duration (sec)
1	1 Jan 1997 07:08:06.41	1 Jan 1997 07:27:07.94	1141.525
2	1 Jan 1997 08:52:48.42	1 Jan 1997 09:11:55.53	1147.108

3	1 Jan 1997 10:40:48.66	1 Jan 1997 10:50:55.18	606.527
4	1 Jan 1997 18:52:34.66	1 Jan 1997 19:10:37.77	1083.110
5	1 Jan 1997 20:36:26.74	1 Jan 1997 20:56:17.86	1191.125
6	1 Jan 1997 22:26:13.89	1 Jan 1997 22:38:48.24	754.346

Global Statistics

Min Iraq-To-Satellite21 - Duration	3	1 Jan 1997 10:40:48.66	1 Jan 1997 10:50:55.18	606.527
Max Iraq-To-Satellite21 - Duration	5	1 Jan 1997 20:36:26.74	1 Jan 1997 20:56:17.86	1191.125
Mean Iraq-To-Satellite21 - Duration			987.290	
Total Iraq-To-Satellite21 - Duration			5923.740	

Iraq-To-Satellite22 - Access	Iraq-To-Satellite22 - Start Time (UTCG)	Iraq-To-Satellite22 - Stop Time (UTCG)	Iraq-To-Satellite22 - Duration (sec)
1	1 Jan 1997 06:42:20.87	1 Jan 1997 06:59:58.72	1057.854
2	1 Jan 1997 08:26:25.12	1 Jan 1997 08:46:15.98	1190.856
3	1 Jan 1997 10:13:06.51	1 Jan 1997 10:27:10.51	844.002
4	1 Jan 1997 18:27:34.99	1 Jan 1997 18:43:46.77	971.777
5	1 Jan 1997 20:09:56.85	1 Jan 1997 20:30:05.67	1208.825
6	1 Jan 1997 21:58:01.40	1 Jan 1997 22:13:47.56	946.160

Global Statistics

Min Iraq-To-Satellite22 - Duration	3	1 Jan 1997 10:13:06.51	1 Jan 1997 10:27:10.51	844.002
Max Iraq-To-Satellite22 - Duration	5	1 Jan 1997 20:09:56.85	1 Jan 1997 20:30:05.67	1208.825
Mean Iraq-To-Satellite22 - Duration			1036.579	
Total Iraq-To-Satellite22 - Duration			6219.473	

Iraq-To-Satellite23 - Access	Iraq-To-Satellite23 - Start Time (UTCG)	Iraq-To-Satellite23 - Stop Time (UTCG)	Iraq-To-Satellite23 - Duration (sec)
1	1 Jan 1997 06:16:56.70	1 Jan 1997 06:32:18.79	922.084
2	1 Jan 1997 08:00:09.86	1 Jan 1997 08:20:13.76	1203.903

3	1 Jan 1997 09:46:04.47	1 Jan 1997 10:02:32.23	987.764
4	1 Jan 1997 18:03:18.00	1 Jan 1997 18:16:32.92	794.917
5	1 Jan 1997 19:43:47.47	1 Jan 1997 20:03:45.43	1197.956
6	1 Jan 1997 21:30:35.13	1 Jan 1997 21:48:13.01	1057.879

Global Statistics

Min Iraq-To-Satellite23 - Duration	4	1 Jan 1997 18:03:18.00	1 Jan 1997 18:16:32.92	794.917
Max Iraq-To-Satellite23 - Duration	2	1 Jan 1997 08:00:09.86	1 Jan 1997 08:20:13.76	1203.903
Mean Iraq-To-Satellite23 - Duration			1027.417	
Total Iraq-To-Satellite23 - Duration			6164.502	

Iraq-To-Satellite3 - Access	Iraq-To-Satellite3 - Start Time (UTCG)	Iraq-To-Satellite3 - Stop Time (UTCG)	Iraq-To-Satellite3 - Duration (sec)
1	1 Jan 1997 00:00:12.76	1 Jan 1997 00:19:30.28	1157.524
2	1 Jan 1997 01:52:03.28	1 Jan 1997 02:00:17.46	494.185
3	1 Jan 1997 09:20:55.02	1 Jan 1997 09:36:46.88	951.853
4	1 Jan 1997 11:04:19.01	1 Jan 1997 11:24:22.13	1203.122
5	1 Jan 1997 12:50:20.91	1 Jan 1997 13:06:27.63	966.723
6	1 Jan 1997 21:07:02.52	1 Jan 1997 21:20:55.66	833.140
7	1 Jan 1997 22:47:54.49	1 Jan 1997 23:07:56.64	1202.141

Global Statistics

Min Iraq-To-Satellite3 - Duration	2	1 Jan 1997 01:52:03.28	1 Jan 1997 02:00:17.46	494.185
Max Iraq-To-Satellite3 - Duration	4	1 Jan 1997 11:04:19.01	1 Jan 1997 11:24:22.13	1203.122
Mean Iraq-To-Satellite3 - Duration			972.670	
Total Iraq-To-Satellite3 - Duration			6808.687	

Iraq-To-Satellite31 - Access	Iraq-To-Satellite31 - Start Time (UTCG)	Iraq-To-Satellite31 - Stop Time (UTCG)	Iraq-To-Satellite31 - Duration (sec)
1	1 Jan 1997 01:22:44.87	1 Jan 1997 01:36:16.74	811.868

2	1 Jan 1997 08:56:07.58	1 Jan 1997 09:08:20.01	732.431
3	1 Jan 1997 10:38:10.60	1 Jan 1997 10:58:05.48	1194.882
4	1 Jan 1997 12:23:34.52	1 Jan 1997 12:41:20.37	1065.845
5	1 Jan 1997 20:43:54.96	1 Jan 1997 20:52:54.20	539.247
6	1 Jan 1997 22:22:04.26	1 Jan 1997 22:41:29.53	1165.266

Global Statistics

Min Iraq-To-Satellite31 - Duration	5	1 Jan 1997 20:43:54.96	1 Jan 1997 20:52:54.20	539.247
Max Iraq-To-Satellite31 - Duration	3	1 Jan 1997 10:38:10.60	1 Jan 1997 10:58:05.48	1194.882
Mean Iraq-To-Satellite31 - Duration				918.257
Total Iraq-To-Satellite31 - Duration				5509.540

Iraq-To-Satellite32 - Access	Iraq-To-Satellite32 - Start Time (UTCG)	Iraq-To-Satellite32 - Stop Time (UTCG)	Iraq-To-Satellite32 - Duration (sec)
1	1 Jan 1997 00:54:46.19	1 Jan 1997 01:11:04.91	978.728
2	1 Jan 1997 10:12:11.96	1 Jan 1997 10:31:24.91	1152.954
3	1 Jan 1997 11:57:00.49	1 Jan 1997 12:15:56.25	1135.759
4	1 Jan 1997 13:45:23.96	1 Jan 1997 13:54:30.06	546.093
5	1 Jan 1997 21:56:34.31	1 Jan 1997 22:14:52.60	1098.290
6	1 Jan 1997 23:40:41.08	2 Jan 1997 00:00:00.00	1158.920

Global Statistics

Min Iraq-To-Satellite32 - Duration	4	1 Jan 1997 13:45:23.96	1 Jan 1997 13:54:30.06	546.093
Max Iraq-To-Satellite32 - Duration	6	1 Jan 1997 23:40:41.08	2 Jan 1997 00:00:00.00	1158.920
Mean Iraq-To-Satellite32 - Duration				1011.791
Total Iraq-To-Satellite32 - Duration				6070.745

Iraq-To-Satellite33 - Access	Iraq-To-Satellite33 - Start Time (UTCG)	Iraq-To-Satellite33 - Stop Time (UTCG)	Iraq-To-Satellite33 - Duration (sec)
1	1 Jan 1997 00:27:25.69	1 Jan 1997 00:45:25.28	1079.591

2	1 Jan 1997 09:46:24.15	1 Jan 1997 10:04:19.39	1075.242
3	1 Jan 1997 11:30:35.70	1 Jan 1997 11:50:21.18	1185.487
4	1 Jan 1997 13:17:27.60	1 Jan 1997 13:30:58.23	810.627
5	1 Jan 1997 21:31:28.77	1 Jan 1997 21:48:03.95	995.173
6	1 Jan 1997 23:14:07.96	1 Jan 1997 23:34:15.47	1207.511

Global Statistics

Min Iraq-To-Satellite33 - Duration	4	1 Jan 1997 13:17:27.60	1 Jan 1997 13:30:58.23	810.627
Max Iraq-To-Satellite33 - Duration	6	1 Jan 1997 23:14:07.96	1 Jan 1997 23:34:15.47	1207.511
Mean Iraq-To-Satellite33 - Duration				1058.939
Total Iraq-To-Satellite33 - Duration				6353.631

Iraq-To-Satellite4 - Access	Iraq-To-Satellite4 - Start Time (UTCG)	Iraq-To-Satellite4 - Stop Time (UTCG)	Iraq-To-Satellite4 - Duration (sec)
1	1 Jan 1997 00:04:43.05	1 Jan 1997 00:17:42.61	779.567
2	1 Jan 1997 01:45:03.78	1 Jan 1997 02:04:59.94	1196.155
3	1 Jan 1997 03:31:46.38	1 Jan 1997 03:49:30.25	1063.873
4	1 Jan 1997 12:50:28.03	1 Jan 1997 13:08:39.12	1091.094
5	1 Jan 1997 14:34:46.64	1 Jan 1997 14:54:25.74	1179.101
6	1 Jan 1997 16:21:50.28	1 Jan 1997 16:34:44.11	773.829

Global Statistics

Min Iraq-To-Satellite4 - Duration	6	1 Jan 1997 16:21:50.28	1 Jan 1997 16:34:44.11	773.829
Max Iraq-To-Satellite4 - Duration	2	1 Jan 1997 01:45:03.78	1 Jan 1997 02:04:59.94	1196.155
Mean Iraq-To-Satellite4 - Duration				1013.936
Total Iraq-To-Satellite4 - Duration				6083.619

Iraq-To-Satellite41 - Access	Iraq-To-Satellite41 - Start Time (UTCG)	Iraq-To-Satellite41 - Stop Time (UTCG)	Iraq-To-Satellite41 - Duration (sec)
1	1 Jan 1997 01:19:19.39	1 Jan 1997 01:38:30.63	1151.239

2	1 Jan 1997 03:04:30.85	1 Jan 1997 03:23:37.47	1146.625
3	1 Jan 1997 04:57:01.91	1 Jan 1997 05:03:38.58	396.665
4	1 Jan 1997 12:24:54.48	1 Jan 1997 12:41:13.49	979.006
5	1 Jan 1997 14:08:28.51	1 Jan 1997 14:28:30.62	1202.108
6	1 Jan 1997 15:54:38.16	1 Jan 1997 16:10:21.98	943.820

Global Statistics

Min Iraq-To-Satellite41 - Duration	3	1 Jan 1997 04:57:01.91	1 Jan 1997 05:03:38.58	396.665
Max Iraq-To-Satellite41 - Duration	5	1 Jan 1997 14:08:28.51	1 Jan 1997 14:28:30.62	1202.108
Mean Iraq-To-Satellite41 - Duration			969.910	
Total Iraq-To-Satellite41 - Duration			5819.462	

Iraq-To-Satellite42 - Access	Iraq-To-Satellite42 - Start Time (UTCG)	Iraq-To-Satellite42 - Stop Time (UTCG)	Iraq-To-Satellite42 - Duration (sec)
1	1 Jan 1997 00:53:53.73	1 Jan 1997 01:11:50.83	1077.100
2	1 Jan 1997 02:37:40.40	1 Jan 1997 02:57:33.51	1193.109
3	1 Jan 1997 04:27:19.32	1 Jan 1997 04:40:10.37	771.049
4	1 Jan 1997 11:59:56.05	1 Jan 1997 12:12:59.29	783.232
5	1 Jan 1997 13:42:18.53	1 Jan 1997 14:02:17.25	1198.723
6	1 Jan 1997 15:27:48.93	1 Jan 1997 15:45:20.29	1051.363
7	1 Jan 1997 23:47:20.46	1 Jan 1997 23:57:30.89	610.426

Global Statistics

Min Iraq-To-Satellite42 - Duration	7	1 Jan 1997 23:47:20.46	1 Jan 1997 23:57:30.89	610.426
Max Iraq-To-Satellite42 - Duration	5	1 Jan 1997 13:42:18.53	1 Jan 1997 14:02:17.25	1198.723
Mean Iraq-To-Satellite42 - Duration			955.000	
Total Iraq-To-Satellite42 - Duration			6685.001	

Iraq-To-Satellite43 - Access	Iraq-To-Satellite43 - Start Time (UTCG)	Iraq-To-Satellite43 - Stop Time (UTCG)	Iraq-To-Satellite43 - Duration (sec)

1	1 Jan 1997 00:28:56.30	1 Jan 1997 00:44:58.84	962.539
2	1 Jan 1997 02:11:11.68	1 Jan 1997 02:31:20.75	1209.070
3	1 Jan 1997 03:59:10.81	1 Jan 1997 04:15:06.30	955.491
4	1 Jan 1997 11:37:17.35	1 Jan 1997 11:42:19.07	301.719
5	1 Jan 1997 13:16:17.94	1 Jan 1997 13:35:41.12	1163.182
6	1 Jan 1997 15:01:12.98	1 Jan 1997 15:19:56.40	1123.418
7	1 Jan 1997 16:50:03.88	1 Jan 1997 16:57:59.67	475.795

Global Statistics

Min Iraq-To-Satellite43 - Duration	4	1 Jan 1997 11:37:17.35	1 Jan 1997 11:42:19.07	301.719
Max Iraq-To-Satellite43 - Duration	2	1 Jan 1997 02:11:11.68	1 Jan 1997 02:31:20.75	1209.070
Mean Iraq-To-Satellite43 - Duration			884.459	
Total Iraq-To-Satellite43 - Duration			6191.215	

Iraq-To-Satellite5 - Access	Iraq-To-Satellite5 - Start Time (UTCG)	Iraq-To-Satellite5 - Stop Time (UTCG)	Iraq-To-Satellite5 - Duration (sec)
1	1 Jan 1997 03:32:49.90	1 Jan 1997 03:49:16.44	986.538
2	1 Jan 1997 05:15:22.80	1 Jan 1997 05:35:30.93	1208.130
3	1 Jan 1997 07:03:36.94	1 Jan 1997 07:19:06.99	930.050
4	1 Jan 1997 14:40:14.21	1 Jan 1997 14:47:50.08	455.877
5	1 Jan 1997 16:20:24.46	1 Jan 1997 16:39:56.66	1172.199
6	1 Jan 1997 18:05:25.96	1 Jan 1997 18:23:57.05	1111.083
7	1 Jan 1997 19:54:51.96	1 Jan 1997 20:01:21.29	389.327

Global Statistics

Min Iraq-To-Satellite5 - Duration	7	1 Jan 1997 19:54:51.96	1 Jan 1997 20:01:21.29	389.327
Max Iraq-To-Satellite5 - Duration	2	1 Jan 1997 05:15:22.80	1 Jan 1997 05:35:30.93	1208.130
Mean Iraq-To-Satellite5 - Duration			893.315	
Total Iraq-To-Satellite5 - Duration			6253.202	

Iraq-To-Satellite51 - Access	Iraq-To-Satellite51 - Start Time (UTCG)	Iraq-To-Satellite51 - Stop Time (UTCG)	Iraq-To-Satellite51 - Duration (sec)
1	1 Jan 1997 03:08:26.99	1 Jan 1997 03:22:06.06	819.070
2	1 Jan 1997 04:49:10.82	1 Jan 1997 05:09:11.51	1200.691
3	1 Jan 1997 06:36:06.84	1 Jan 1997 06:53:34.91	1048.078
4	1 Jan 1997 15:54:32.62	1 Jan 1997 16:12:58.74	1106.123
5	1 Jan 1997 17:38:58.02	1 Jan 1997 17:58:29.69	1171.662
6	1 Jan 1997 19:26:14.81	1 Jan 1997 19:38:27.91	733.100

Global Statistics

Min Iraq-To-Satellite51 - Duration	6	1 Jan 1997 19:26:14.81	1 Jan 1997 19:38:27.91	733.100
Max Iraq-To-Satellite51 - Duration	2	1 Jan 1997 04:49:10.82	1 Jan 1997 05:09:11.51	1200.691
Mean Iraq-To-Satellite51 - Duration				1013.121
Total Iraq-To-Satellite51 - Duration				6078.724

Iraq-To-Satellite52 - Access	Iraq-To-Satellite52 - Start Time (UTCG)	Iraq-To-Satellite52 - Stop Time (UTCG)	Iraq-To-Satellite52 - Duration (sec)
1	1 Jan 1997 02:45:29.51	1 Jan 1997 02:53:56.92	507.406
2	1 Jan 1997 04:23:22.13	1 Jan 1997 04:42:43.75	1161.628
3	1 Jan 1997 06:08:50.07	1 Jan 1997 06:27:44.51	1134.438
4	1 Jan 1997 08:02:16.94	1 Jan 1997 08:06:39.55	262.608
5	1 Jan 1997 15:28:55.11	1 Jan 1997 15:45:38.82	1003.707
6	1 Jan 1997 17:12:38.43	1 Jan 1997 17:32:38.76	1200.322
7	1 Jan 1997 18:58:56.31	1 Jan 1997 19:14:15.28	918.969

Global Statistics

Min Iraq-To-Satellite52 - Duration	4	1 Jan 1997 08:02:16.94	1 Jan 1997 08:06:39.55	262.608
Max Iraq-To-Satellite52 - Duration	6	1 Jan 1997 17:12:38.43	1 Jan 1997 17:32:38.76	1200.322
Mean Iraq-To-Satellite52 - Duration				884.154
Total Iraq-To-Satellite52 - Duration				6189.078

Iraq-To-Satellite53 - Access	Iraq-To-Satellite53 - Start Time (UTCG)	Iraq-To-Satellite53 - Stop Time (UTCG)	Iraq-To-Satellite53 - Duration (sec)
1	1 Jan 1997 03:57:53.31	1 Jan 1997 04:16:06.01	1092.701
2	1 Jan 1997 05:41:54.73	1 Jan 1997 06:01:42.26	1187.523
3	1 Jan 1997 07:31:56.63	1 Jan 1997 07:44:01.64	725.010
4	1 Jan 1997 15:03:47.79	1 Jan 1997 15:17:35.58	827.790
5	1 Jan 1997 16:46:26.92	1 Jan 1997 17:06:28.46	1201.533
6	1 Jan 1997 18:32:03.95	1 Jan 1997 18:49:19.51	1035.558

Global Statistics

Min Iraq-To-Satellite53 - Duration	3	1 Jan 1997 07:31:56.63	1 Jan 1997 07:44:01.64	725.010
Max Iraq-To-Satellite53 - Duration	5	1 Jan 1997 16:46:26.92	1 Jan 1997 17:06:28.46	1201.533
Mean Iraq-To-Satellite53 - Duration			1011.686	
Total Iraq-To-Satellite53 - Duration			6070.115	

Iraq-To-Satellite6 - Access	Iraq-To-Satellite6 - Start Time (UTCG)	Iraq-To-Satellite6 - Stop Time (UTCG)	Iraq-To-Satellite6 - Duration (sec)
1	1 Jan 1997 07:01:53.92	1 Jan 1997 07:20:20.97	1107.049
2	1 Jan 1997 08:46:10.00	1 Jan 1997 09:05:50.85	1180.846
3	1 Jan 1997 10:36:37.39	1 Jan 1997 10:47:49.69	672.301
4	1 Jan 1997 18:07:42.19	1 Jan 1997 18:22:09.37	867.184
5	1 Jan 1997 19:50:35.78	1 Jan 1997 20:10:39.07	1203.293
6	1 Jan 1997 21:36:19.52	1 Jan 1997 21:53:17.94	1018.418

Global Statistics

Min Iraq-To-Satellite6 - Duration	3	1 Jan 1997 10:36:37.39	1 Jan 1997 10:47:49.69	672.301
Max Iraq-To-Satellite6 - Duration	5	1 Jan 1997 19:50:35.78	1 Jan 1997 20:10:39.07	1203.293
Mean Iraq-To-Satellite6 - Duration			1008.182	
Total Iraq-To-Satellite6 - Duration			6049.090	

Iraq-To-Satellite61 - Access	Iraq-To-Satellite61 - Start Time (UTCG)	Iraq-To-Satellite61 - Stop Time (UTCG)	Iraq-To-Satellite61 - Duration (sec)
1	1 Jan 1997 06:36:44.84	1 Jan 1997 06:53:33.61	1008.775
2	1 Jan 1997 08:19:34.78	1 Jan 1997 08:39:41.00	1206.215
3	1 Jan 1997 10:08:04.70	1 Jan 1997 10:23:06.66	901.964
4	1 Jan 1997 17:43:41.82	1 Jan 1997 17:52:54.61	552.790
5	1 Jan 1997 19:24:31.55	1 Jan 1997 19:44:11.53	1179.987
6	1 Jan 1997 21:09:39.38	1 Jan 1997 21:27:58.17	1098.788
7	1 Jan 1997 23:00:06.05	1 Jan 1997 23:04:27.05	261.004

Global Statistics

Min Iraq-To-Satellite61 - Duration	7	1 Jan 1997 23:00:06.05	1 Jan 1997 23:04:27.05	261.004
Max Iraq-To-Satellite61 - Duration	2	1 Jan 1997 08:19:34.78	1 Jan 1997 08:39:41.00	1206.215
Mean Iraq-To-Satellite61 - Duration			887.075	
Total Iraq-To-Satellite61 - Duration			6209.522	

Iraq-To-Satellite62 - Access	Iraq-To-Satellite62 - Start Time (UTCG)	Iraq-To-Satellite62 - Stop Time (UTCG)	Iraq-To-Satellite62 - Duration (sec)
1	1 Jan 1997 06:12:13.26	1 Jan 1997 06:26:28.30	855.043
2	1 Jan 1997 07:53:18.71	1 Jan 1997 08:13:22.98	1204.272
3	1 Jan 1997 09:40:27.64	1 Jan 1997 09:57:39.11	1031.468
4	1 Jan 1997 18:58:37.91	1 Jan 1997 19:17:18.62	1120.706
5	1 Jan 1997 20:43:09.81	1 Jan 1997 21:02:32.99	1163.183
6	1 Jan 1997 22:30:41.41	1 Jan 1997 22:42:09.27	687.858

Global Statistics

Min Iraq-To-Satellite62 - Duration	6	1 Jan 1997 22:30:41.41	1 Jan 1997 22:42:09.27	687.858
Max Iraq-To-Satellite62 - Duration	2	1 Jan 1997 07:53:18.71	1 Jan 1997 08:13:22.98	1204.272
Mean Iraq-To-Satellite62 - Duration			1010.422	
Total Iraq-To-Satellite62 - Duration			6062.531	

Iraq-To-Satellite63 - Access	Iraq-To-Satellite63 - Start Time (UTCG)	Iraq-To-Satellite63 - Stop Time (UTCG)	Iraq-To-Satellite63 - Duration (sec)
1	1 Jan 1997 05:48:51.70	1 Jan 1997 05:58:36.81	585.110
2	1 Jan 1997 07:27:25.79	1 Jan 1997 07:46:56.76	1170.966
3	1 Jan 1997 09:13:10.43	1 Jan 1997 09:31:51.29	1120.857
4	1 Jan 1997 18:32:56.87	1 Jan 1997 18:50:02.97	1026.099
5	1 Jan 1997 20:16:48.77	1 Jan 1997 20:36:46.31	1197.535
6	1 Jan 1997 22:03:15.30	1 Jan 1997 22:18:07.41	892.103

Global Statistics

Min Iraq-To-Satellite63 - Duration	1	1 Jan 1997 05:48:51.70	1 Jan 1997 05:58:36.81	585.110
Max Iraq-To-Satellite63 - Duration	5	1 Jan 1997 20:16:48.77	1 Jan 1997 20:36:46.31	1197.535
Mean Iraq-To-Satellite63 - Duration			998.778	
Total Iraq-To-Satellite63 - Duration			5992.670	

Iraq-To-Satellite7 - Access	Iraq-To-Satellite7 - Start Time (UTCG)	Iraq-To-Satellite7 - Stop Time (UTCG)	Iraq-To-Satellite7 - Duration (sec)
1	1 Jan 1997 00:33:18.06	1 Jan 1997 00:50:39.40	1041.348
2	1 Jan 1997 08:52:21.81	1 Jan 1997 09:03:10.92	649.105
3	1 Jan 1997 10:31:30.27	1 Jan 1997 10:51:09.53	1179.256
4	1 Jan 1997 12:17:31.89	1 Jan 1997 12:35:57.63	1105.740
5	1 Jan 1997 21:36:59.58	1 Jan 1997 21:54:25.90	1046.325
6	1 Jan 1997 23:20:59.39	1 Jan 1997 23:40:53.15	1193.760

Global Statistics

Min Iraq-To-Satellite7 - Duration	2	1 Jan 1997 08:52:21.81	1 Jan 1997 09:03:10.92	649.105
Max Iraq-To-Satellite7 - Duration	6	1 Jan 1997 23:20:59.39	1 Jan 1997 23:40:53.15	1193.760
Mean Iraq-To-Satellite7 - Duration			1035.922	
Total Iraq-To-Satellite7 - Duration			6215.535	

Iraq-To-Satellite71 - Access	Iraq-To-Satellite71 - Start Time (UTCG)	Iraq-To-Satellite71 - Stop Time (UTCG)	Iraq-To-Satellite71 - Duration (sec)
1	1 Jan 1997 00:06:40.79	1 Jan 1997 00:25:16.29	1115.495
2	1 Jan 1997 01:55:52.86	1 Jan 1997 02:02:55.73	422.864
3	1 Jan 1997 10:05:55.42	1 Jan 1997 10:24:35.63	1120.215
4	1 Jan 1997 11:50:26.13	1 Jan 1997 12:09:59.13	1173.002
5	1 Jan 1997 13:41:22.46	1 Jan 1997 13:51:35.64	613.179
6	1 Jan 1997 21:11:38.70	1 Jan 1997 21:26:40.95	902.243
7	1 Jan 1997 22:54:44.96	1 Jan 1997 23:14:48.99	1204.026

Global Statistics

Min Iraq-To-Satellite71 - Duration	2	1 Jan 1997 01:55:52.86	1 Jan 1997 02:02:55.73	422.864
Max Iraq-To-Satellite71 - Duration	7	1 Jan 1997 22:54:44.96	1 Jan 1997 23:14:48.99	1204.026
Mean Iraq-To-Satellite71 - Duration			935.861	
Total Iraq-To-Satellite71 - Duration			6551.024	

Iraq-To-Satellite72 - Access	Iraq-To-Satellite72 - Start Time (UTCG)	Iraq-To-Satellite72 - Stop Time (UTCG)	Iraq-To-Satellite72 - Duration (sec)
1	1 Jan 1997 01:27:25.42	1 Jan 1997 01:39:53.49	748.070
2	1 Jan 1997 09:40:40.93	1 Jan 1997 09:57:50.34	1029.410
3	1 Jan 1997 11:23:47.51	1 Jan 1997 11:43:50.83	1203.315
4	1 Jan 1997 13:12:34.15	1 Jan 1997 13:27:04.95	870.806
5	1 Jan 1997 20:47:16.15	1 Jan 1997 20:57:47.98	631.828
6	1 Jan 1997 22:28:39.07	1 Jan 1997 22:48:25.65	1186.574

Global Statistics

Min Iraq-To-Satellite72 - Duration	5	1 Jan 1997 20:47:16.15	1 Jan 1997 20:57:47.98	631.828
Max Iraq-To-Satellite72 - Duration	3	1 Jan 1997 11:23:47.51	1 Jan 1997 11:43:50.83	1203.315
Mean Iraq-To-Satellite72 - Duration			945.000	

Total Iraq-To-Satellite72 - Duration 5670.002

Iraq-To-Satellite73 - Access	Iraq-To-Satellite73 - Start Time (UTCG)	Iraq-To-Satellite73 - Stop Time (UTCG)	Iraq-To-Satellite73 - Duration (sec)
1	1 Jan 1997 01:00:09.28	1 Jan 1997 01:15:37.33	928.045
2	1 Jan 1997 09:16:01.47	1 Jan 1997 09:30:49.51	888.039
3	1 Jan 1997 10:57:27.35	1 Jan 1997 11:17:34.23	1206.881
4	1 Jan 1997 12:44:49.53	1 Jan 1997 13:01:42.60	1013.073
5	1 Jan 1997 22:02:43.59	1 Jan 1997 22:21:37.54	1133.953
6	1 Jan 1997 23:47:21.87	2 Jan 1997 00:00:00.00	758.134

Global Statistics

Min Iraq-To-Satellite73 - Duration	6	1 Jan 1997 23:47:21.87	2 Jan 1997 00:00:00.00	758.134
Max Iraq-To-Satellite73 - Duration	3	1 Jan 1997 10:57:27.35	1 Jan 1997 11:17:34.23	1206.881
Mean Iraq-To-Satellite73 - Duration			988.021	
Total Iraq-To-Satellite73 - Duration			5928.125	

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